VAN NOSTRAND'S

ECLECTIC

ENGINEERING MAGAZINE.

NO. LXXXVI.—FEBRUARY, 1876.—VOL. XIV.

LIGHT-HOUSES.*

Good light-houses are legitimate objects of national pride; monuments alike of engineering skill and of the nation's regard for the commerce of the seas, they are conspicuous indices of advanced civilization.

A healthful rivalry at present exists between the leading European nations in the matter of lighting their coasts; each, however, adopting any well tried improvement independent of its origin. That the efforts of our own country are in the right direction may be inferred from the character of the report of Maj. Elliot, made as it was under the direction of the Secretary of the Treasury. The extent and thoroughness of this tour of inspection is an earnest of the intention on part of our Government to compete in this peaceful strife.

Already have we contributed something both in the way of signaling and in the matter of foundations for the more common forms of light-house structures on bars or shores of low altitude; but the report assures us "both England and France are in advance of us in using both gas and electric lights in positions of special importance—in the use of azimuthal condensing prisms for certain localities; in the character of their lamps; in the use of fog-signals in light-ships; in their light-ships with revolving lights; and, more than all, in the character of their keepers, who are in service during good behavior until death or superannuation, who are promoted for merit, and whose lives are insured by the Government for the benefit of their families."

Of the character of the problems to be solved in lighting a coast and of the general method of solving them, we can give no better idea than by quoting from our cotemporary, *The Building News*, an account of the French system of light-houses, simply premising that in all that pertains to the most advanced ideas in this branch of engineering, our Gothic friends have no superiors:

"France, it may now be said, has almost completed her lighthouse system, ranging from Dunkirk to Socoa, from Port Vendres to Nice, and, taken as a whole, it exhibits a marvel, at once, of national enterprise and of engineering ingenuity. As is well known, an entirely new science and practice have been created, of recent years, with respect to these beacons, warning the mariner of his approach to land of any kind; but especially to capes, headlands, reefs, and shallows. It is now the established custom to erect the loftiest structures, bearing the most powerful lights, upon the most elevated promontories, or nearest to the most dangerous rocks, and to

* European Light-House Systems; being a Report of a Tour of Inspection in 1873, by Maj. Geo. H. Elliot, Corps of Engineers, U. S. A. New York: D. Van Nostrand.

plant them at such distances one from another that it would be next to impossible, assuming commonly careful seamanship, or a fog so dense as to be impenetrable by either natural or artificial light, that the shore should be approached without one or another being seen. By arranging, from point to point, the alternating flashes and obscurations of the lamps a guide is given to the vessel, which, if studiously followed, proves generally a perfect safeguard. Along the bays, however, necessarily intervening between these principal edifices, and into which sea-going ships need not enter, are supplied, for the sake of coasters and small craft, illuminations of a second and third-rate order, indicating perilous thrusts of the land into the sea, hidden rocks, and sandbanks, and the entrances to harbors and ports. Thus the coast of the Gironde, an immense resort of commerce, has no fewer than eleven light-houses of the three classes, with others of yet a different description, being simply signal-lanterns, hoisted above quays and piers, to signify whether or not they may be safely approached. But it is not with the nature of the lamps, the colors of the lights, or the character of the oil, or the apparatus employed, that the last report deals in its most important sections : it is with the structures themselves. They should, say the Commission of Light-house Architects, be so built as to satisfy numerous difficult conditions. They must be lofty, in order that the sailor may perceive, from a distance, their friendly flames. Occasionally, it may happen that they can be pitched upon the summit of some natural height, as that on Cape Bearn, or on the crest of a cliff, as those of Ailly, Fécamp, and Heve, on the Norman coast, in which case it suffices that the tower shall be high enough for its lantern not to be concealed by trees, churches, or houses, or liable to be damaged by mischief-doers. But frequently the necessities of navigation render it compulsory that the light-house should be built on the very edge of the sea, or even upon a rock, or group of rocks, whose surface is level with the water. Here the same necessity exists for a considerable altitude, since no French light-house, of the first-class, is regarded as effective unless its beacon burns at an elevation of at least a hundred feet above the level of the sea. The principal of them, however, are much loftier—that of Cordouan 200, which all but tops the towers of Notre-Dame ; that of Dunkirk, 175 ; that of Calais, 160 ; and that on the Isle de Ré, the same. Practically, it is found difficult, if not impossible, that these slender edifices should possess, in all their height, the qualities of massiveness and enduring solidity ; and it is all the more necessary, therefore, we are reminded, that their construction should be the most elaborate, and, above all, their foundations reared as if intended to be fortresses to resist the attacks of the sea. This, however, as is recorded in the annals of some among our more famous English edifices of the kind, is particularly difficult when the basis is a sand-bank, liable to shifting or submersion. The weight to be borne, it must be remembered, is not that of the lantern alone. There must be store-rooms, stores, apartments for the keepers, and so forth. Moreover, scarcely any structure of the sort was ever piled up which did not, at times, reel and bend beneath the violence of the tempest—a fact calling for the utmost possible perfection of masonry ; yet, in spite of all, the doom of not a few is already pronounced. For example, the central light-house of Cape Ailly has been declared, notwithstanding its slimness, its thick walls, so harmonious in proportion, so little weakened by the ipternal staircase and external windows, that it seemed destined to stand for ages. But the Cape of chalk, whence it rises, has, since its construction, been more than half demolished by the waves, and the day must certainly come when that Norman Pharos must fall headlong into the waters—a circumstance upon which the Architectural Commissioners comment in discussing the question of future sites. Still more remarkable than this, however, is the Tower of Cordouan, at the mouth of the Garonne, which has stood since the end of the sixteenth century, on a rock covered, at high tide, by 12ft. of water. The architect made of it a labor of love, and lavished upon it an excess of decoration. His original building was only 100ft. high, and mariners complained that they could not see the light from sufficiently far. Two

centuries later a daring architect proposed to make it 80ft. higher, and to rear above the sculptured chambers of the first and second stories an additional structure, obelisk-shaped, the joining of the old with the new being guaranteed by him to produce no cause of weakness. His pledge was fulfilled. No "weakest point" was ever proved in the Tower of Cordouan. As to the processes by which this marvelous edifice was erected, there exist, unfortunately, no records. Another celebrated French light-house is that of Fléaux de Brehat, a recent erection, based upon a huge and treacherous porphyry rock, for ages the terror of every seaman who approached the Brittany coast. Its architect had to encounter every species of obstacle during his work, but, above all, incessant races and eddies of the sea among the neighboring sandbanks. The foundations had to be sought for far beneath low-water; an artificial port had to be created; the necessary stonework was hewn and shaped on the Island of Brehat, seven miles distant. Even when the foundations had appeared above the water the lower walls of the lower story were submerged twice a day, leaving heavy deposits of marine plants, shells, and seaweed. The workmen lived in huts upon a reef, to which they retired when the tide rose; and thus they pushed on their labors, quarrying and squaring at one time, arranging and fixing at another. Their's was a masonry almost without mortar. The blocks were grooved and literally dovetailed together, the course being connected, as it were, by cogs, so that every part relied upon every other, the result being, as nearly as possible, an absolute cohesion. In spite of this happy issue the reporting architects would not recommend similar experiments in the future. Such works, they urge, are costly, and their success is uncertain. The day may come, too, they add, when for all this invention may be substituted structures of concrete, or of a cement which, in the course of a few hours, will change into the hardness and consistency of granite—a process, they inform us, which has already been resorted to in the construction of many of the minor French light-house towers—the martellos of the system. Of the higher class, indeed, some are built of other materials than stone—of iron, in fact, wrought and cast, such as stand along the less-frequented coasts, or on the shores of colonial territories with small financial resources. Thus, there was lately constructed at Paris a metallic light-house, 130 ft. in elevation, which was carried in pieces to New Caledonia, where it was set up, and now indicates the safest approach to the anchorage of Port de France. There is another of this class at Pontaillac, near Royau, and a third, subsidiary to the great historical light-house of Calais. But there are positions of this coast where it has been found impossible heitherto to maintain a permanent structure of any kind, and where nothing can be provided beyond a stationary life-boat, so to speak, anchored by cables of tremendous strength and surmounted by masts out of all proportion to their size, and bearing aloft a brilliant lantern. These, however, are devices with which French architects are by no means satisfied, since they affirm that, with adequate determination, a foundation can be discovered, whether on the land or beneath shallow sea, anywhere. In point of fact, they stigmatize them all as provisional, and will not in any way admit that light-house science has exhausted its resources merely because a few projectors have been baffled, and they signalize a variety of English triumphs in this direction which ought, in their opinion, to shame every one out of his apprehensions. There is not much, however, for France to be ashamed of in this respect. Along her shores upwards of 300 beacons are kindled every night for the guardianship of the navigator. It would be impossible to follow the commission in its tracing of their distribution; but of the cheif structures—that is, of those whose rays are visible from a distance of from 18 to 25 miles—there are three in the channel, at Dunkirk, at Calais, and at cape Grisnez, which should always, in ordinary weather, be visible from one point or another of the British coast. The first obscures itself each alternate minute, the second sends a flash once in every three or four minutes, the third every 30 seconds, so that it is impossible to confuse or mistake them. In conjunction

with these are two of the second order —those of Gravellines and Walde—the one with a fixed white and the other with a fixed red flame. No seaway in the world is better lighted from the land. The peninsula of Brittany, beset by a swarm of shoals and islets, requires no fewer than 17 light-houses, while from the mouth of the Garonne to the Spanish frontier there are only three, so rarely interrupted are those dismal waters. This is a circumstance due to the accidents of population and commerce. Another, of a different kind, though equally interesting, applies to the sea-board along the Mediterranean. There the atmosphere is usually, even by night, so transparent, and the dangers are so few, that seven light-houses only, of the first order, with a small number of inferior beacons, suffice for that great stretch of coast. A similar remark is applicable to the Corsican and to the Algerian waters. The commission, therefore, deprecates any profuse expenditure upon such works in the interest of sea-boards thus naturally protected. It is not to be supposed, because this notice of the report is necessarily too brief to include even a summary of its whole contents, that the collateral topics connected with this great object are neglected. On the contrary, specific attention is devoted to light-house lamps, from the Argand to the Dioptric, and downwards; those employed by the French, to this day, being almost universally fed with what is known as Colza—or, in plain language, cabbage—oil, each light fed with this, costing on an average £300 a year. But the positive construction and working of the French Pharos appeared nearer to our purpose. With regard to the latter, it is now, in general, effected by means of a small steam-engine, though numberless experiments are still being tried in association with this active power. The steam-engine, moreover, affords another advantage. In the event of weather too dense to admit of the most brilliant flashes being visible at any distance great enough to be of service to the mariner, it can be used to blow the fog-horn with an effect that can be heard for miles, however heavy the atmosphere, and whatever may be the influences interrupting light or sound. Altogether, when the Ministry of Marine think fit to publish this newest of Parisian Blue-books, it will be found to contain a great abundance and variety of information upon a subject of distinct importance, and particularly with reference to the mechanism and management of light-houses. The interest of the matter is enhanced by the proposal of an international emulation, in which the inventors of light-house lamps and lantern-houses shall compete. But this idea has taken no definite form as yet."

We append some abstracts from Maj. Elliot's record of his tour along the English and Irish coasts:

We passed the Mucking light-house, situated in the Thames, below Gravesend, and the Maplin Sand light-house, off the mouth of that river. Both of these are screw-pile structures; the latter was, I believe, the second of that kind in the world, having been lighted in 1841, and was one of the earliest applications of that useful invention of Mitchell, of which we have many examples, there being more than fifty light-houses built on that plan in the United States.

It may be mentioned here that the first screw-pile light-house was built at the mouth of the River Wyre, on the northwest coast of England, two or three years before the light-house on the Maplin Sand. The screws were three feet in diameter, the piles five inches; and above the ground, instead of iron, as at Maplin, wooden columns were used. This light-house was destroyed in 1870.

The Maplin Sand Light-house (a view of which is shown) is a hexagonal structure, with one central and eight exterior piles. The piles were driven vertically, but above the water-line they bent toward the center and incline in a pyramidal form to the lantern-floor. The screws are four feet in diameter, the piles five inches, and they support cast-iron columns 12 inches in diameter. The columns are very strongly braced, and the structure had an appearance of great strength.

We stopped at the Gunfleet Light-house, situated on a sand of that name, north of the mouth of the Thames, and thirty-one miles from the Nore Light-ship. It is exposed to the full force of the North Sea.

There are one central and six exte... piles supporting columns of about 12 inches in diameter, strongly braced.

The sockets for the columns are not cast in one with the sockets for the braces, but the latter are bolted against the face of the piles by tap-bolts.

Unlike Maplin Sand Light-house, the

MAPLIN SAND LIGHT-HOUSE.

piles were not driven vertically, and are inclined from the bottom to the top in the form of a pyramid. The piles, braces, and sockets are of a very massive

character, and give an appearance of great durability and of the strength which the sight demands.

The dwelling for the keepers (below the lantern-floor) is but one story in height, and is smaller and less convenient than in similar structures in the United States. The sides and roof are made of corrugated iron with wrought-iron angle plates. Below the floor of the dwelling additional space is furnished by placing a store room in an inverted pyramid, to which access is had by a ladder from the gallery. The dwelling is divided into a living room (also used as a kitchen), a bed room and an oil room. It was stated that the sea rarely rises to the bottom of the house, and the object of the peculiar form given was to allow the wind and spray to be warded off without imparting shocks to the structure. I should judge the device to be one of questionable utility, and that but little more expense would have been incurred by raising the building a few feet higher and placing another full story for the accommodation of the keepers.

There are two keepers, one less than we would have in the United States, and it will be observed throughout this report that the British lights are maintained by a less number of keepers for each than for the same order of light in our service.

The lantern, which is large and commodious, contains a revolving catoptric apparatus composed of fifteen reflectors and Argand burners in sets of five, placed on a frame of three sides, and this being a red light, panes of red glass, in frames hung on hinges, were placed in front of each reflector. This structure seems admirably adapted to the locality, and I should think the question of replacing by similar structures some of the great number of light-ships which mark the channels through the shoals obstructing navigation on the east coast of England, would have attracted attention, and there are probably some special reasons why it has not been done.

While the first cost of a screw pile light-house in an exposed locality is greater than that of a light-ship, the cost of maintenance as well as of repairs is much less; and besides, the danger which sometimes occurs of light-ships being dragged from their stations and leading vessels into the very dangers from which they are intended to warn them, is avoided.

These considerations have induced us to replace our light-ships by screw pile light-houses except in the case of shifting shoals like those off the Island of Nantucket.

The Outer Farne or Longstone Light-house is, with the exception of a small pier light at Berwick, at the mouth of the Tweed, the most northern of the North Sea lights of England, and is in view of the light on St. Abb's Head, the first of the Scottish lights.

It is a rock light-house of the peculiar construction shown in the Plate, the tower and dwellings being surrounded by high walls to protect them from the sea, which frequently rolls with great violence over the rock, which is long and narrow.

A new first order revolving lens, made by Chance Brothers & Co., has recently been placed in the tower, and the entire station has been repaired and refitted, the mechanics being still at work at the time of my visit.

While at Coquet Island I saw this light very distinctly from the deck of the Vestal, say 10 feet above the sea, at a distance of twenty miles, which was remarkable, as the focal plane is but 85 feet above the sea.

There is only the ordinary number of keepers (two) at this station, but they are supplied with provisions from the mainland and but rarely leave the rock.

This light-house is interesting as having been the home of Grace Darling, the daughter of a former keeper, and to whom owed their rescue the nine out of the sixty-three who were on the Forfarshire when she struck the "Hawker Rock," near the Longstone, on the 5th of September, 1838.

The keepers had much pride in showing us the bed-closet occupied by the heroine and the window through which she first saw the wreck. A beautiful tomb is erected in her memory, at Bamborough Castle, near by on the mainland.

Wicklow Head, on the western side of Saint George's Channel, south of Dublin, we reached partly by rail and partly by "jaunting-car," a two-wheeled

vehicle, which is the common conveyance of the country.

The gas-house, containing the furnaces and retorts, the gas-holder and other buildings, are ingeniously disposed on the face of a high cliff, and occupy but little space, as shown by the frontispiece.

This is a first order intermittent light, the lens-apparatus being that of an ordinary fixed light. The gas is let on and

THE LONGSTONE LIGHT-HOUSE.

shut off by an automatic arrangement which allows ten seconds of light and three seconds of darkness. This arrangement does not cut the gas entirely off, and each jet during the three seconds' eclipse shows a tiny blue flame, which, while it produces no illumination of the lenticular apparatus and can scarcely be

detected in the daylight, is still sufficient to light the main body of gas when the supply is turned on.

To guard against all danger of total extinguishment of the light by gusts of wind through the ventilators or door of the lantern, each jet is surrounded by a small pipe called the "by-pass," the top of which, being at a level with the tip of the jet, is pierced by several minute holes through which gas is supplied from a pipe quite independent of the automatic cut-off; thus protected, these little jets of flame burn from the moment of lighting at sunset to that of extinguishing at sunrise, and it is impossible even if the "cut-off" or a gust of wind should completely extinguish the main flame that the burner should not be lighted at regular intervals of thirteen seconds.

The two keepers at Wicklow Head agreed with those at Howth Baily in saying that the gas gives very much less trouble than the oil light.

Mr. Wigham has invented a gas gun, to be used as a fog signal at stations illuminated by gas; and I had an opportunity of testing it, both at the manufactory in Dublin and at Howth Baily light-station. Captain Hawes kindly directed that the gun should be fired during our observation of the triform-light from Kingstown, so that, at a distance of six miles, I could judge of its efficiency as a signal.

The gun is simply a tube of iron connected with the gasholder by a half inch pipe; in fact, in these experiments the guns were nothing more than pieces of ordinary gas or water pipe of different diameters. The charge of the gun is a mixture of oxygen, coal gas and common air, one-fourth of the mixture being common air and the remainder composed of equal volumes of oxygen and ordinary illuminating gas.

The proper quantities of the gases are allowed to flow from their respective reservoirs into a holder, and the mixture is thence transferred to the closed end of the pipe or breech of the "gun," the flow being regulated by a stop-cock. The mixture is lighter than common air, and when it fills the feed-pipe and gun, the latter being lower than the source of supply, it will remain charged or full until fired, which may be done by touching a match to an orifice at any point of the connecting-pipe desired, taking care that communication with the holder is closed by the stop-cock.

The product of the explosion is carbonic acid gas and water, and, as the latter would rapidly fill any part of the feed-pipe which might be lower than the gun, it would probably be a fatal objection to the use of the invention which immediately suggests itself, viz., its application as a fog signal on outlying rocks difficult to approach or nearly submerged. The defect is all the more to be regretted, as it is at precisely these points that fog-signals are most needed and the erection of other kinds are impracticable.

At Mr. Wigham's extensive works at Dublin the feed-pipe was several hundred feet long.

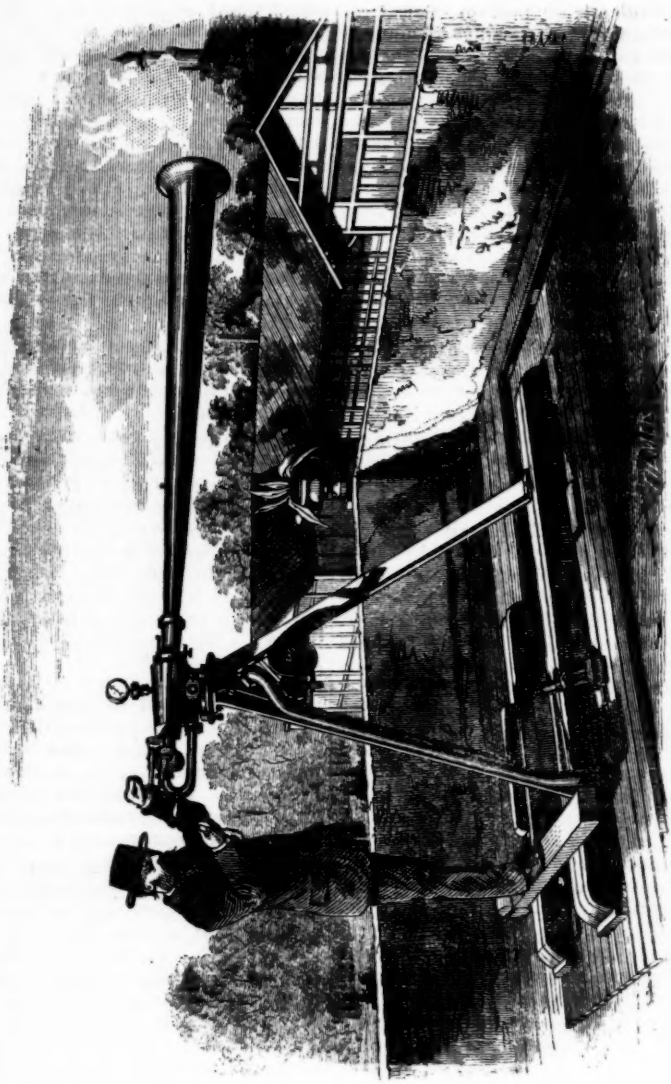
The use of the gun at any gas-light station would be extremely simple, and the keeper need not go to the gun itself, but could easily fire it from his watch-room at the required intervals. I do not know that the experiment has even been tried, but it will readily be seen that by using the electric spark the service of the gun might be made still easier, for a system of clock-work connected with a battery could be easily devised by which an electric circuit could be formed and a spark produced at any desired interval, and thus the gun be fired without any attention on the part of the keeper except what might be required to keep the apparatus in order.

At Howth Baily the guns were twelve inches in diameter and from six to nine feet long. The latter were duplicated, and consisted of two connected pipes, fired simultaneously. Near at hand the reports seemed loud and clear, but when heard from Kingstown a high wind prevailed over Dublin Bay, and I was disappointed in the results. It is true that the distance was six miles, and a comparison with other signals would have been more satisfactory, but I fancied that the 18-pounder fog-signal gun at North Stack, on the other side of the channel, would have been more distinctly heard under the same circumstances.

The flash from this gun is said to illuminate fog much better than that from a gunpowder-gun.

I have no doubt of the utility of the

invention for fog signals at stations illuminated by gas, if the very great expense attending the manufacture of oxygen can be overcome ; and, as Professor Tyndall is now charged by the Board of Trade with the conduct of a complete series of experiments with the gas-gun, it is to be hoped that the inven-



THE AUSTRIAN FOG TRUMPET. (NEBELHORN.)

tive genius of Mr. Wigham will overcome all objections to which it may now be subject.

In concluding my observations on Irish lights I must express sincere thanks to the commissioners and to Captain Hawes, the very intelligent inspector of lights, as well as to Mr. Lees, the secre-

tary of the board, and to Mr. Wigham, for the pleasure and instruction I derived during my limited sojourn in Ireland.

Of Fog-Signals the following account is taken from a later portion of the report accompanying the plate, which is copied from the photograph sent by Mr. Jay, represents the fog-trumpet as I saw it at the exhibition at Vienna, and the following is a translation from the Italian of the description which accompanied it:

"Since the introduction of acoustic signals, used in America as well as in Europe to mark dangerous points on the coast in foggy weather, it has become desirable to have a more perfect instrument, an apparatus that can be used not only at light-stations in foggy weather and snow-storms, but also on board of ships, especially on steamers, not only as an alarm but as a signal for correspondence.

"This object has been fully accomplished by the invention of Giovanni Amadi, of the Technical Institute of Trieste. His trumpet was exhibited at the universal exposition at Vienna, and was awarded a medal of merit.

"This apparatus, which consists of a trumpet, formerly operated by compressed air, but now directly by steam, is provided with an automatic distributing steam-valve, and with a special valve with finger-board (operating keys) so as to produce sounds at will.

"The instrument has a most extraordinary power in proportion to its dimensions and to the pressure of steam required to produce the vibrations; it can be put up either directly over the boiler or separately, and connected with it by a pipe, and it can be turned to any part of the horizon.

"In addition to its use as a fog-signal on shore, it may be applied on board of steamers of whatever steam-power, and is especially advantageous on board of men-of-war.

"By means of the finger-board, one is enabled to give long and short sounds at will with great accuracy, and communications may be made at night, in fog, or in snow-storms, by means of an alphabetic formula similar to that used in telegraphy.

"The trumpet is operated by a steam-boiler of eight horse-power and a pressure of twenty-five pounds per square inch.

"The boiler is more than sufficient to produce thirty blasts in thirty seconds, which are audible at a distance of fifteen nautical miles in clear weather.

"Connected with the boiler is a small machine, which operates the automatic distributing steam-valve and can be so regulated that the different intervals in the sounds distinguish the different stations where trumpets are used.

"In the Technical Institute at Trieste, where this trumpet was constructed, it was very particularly tested, and the government officers at Trieste testified that the sounds were plainly audible at a distance of fifteen miles, the height of the trumpet being thirty English feet above the sea; also that when operated with the finger-board, the signals, according to Morse's method, could be plainly distinguished at a distance of six nautical miles.

"The Austrian goverment purchased this trumpet to operate it on Point Salvore, Istria, after trial of a smaller one of the same kind (audible five miles) near the light-house at Trieste.

"A third trumpet, with a steam generator of two horse-power, and audible eight miles, has also been ordered and finished, and will be put in operation on board of the light-ship anchored at Grado."

In the matter of specific character of signals at different stations, the following extract from a late paper before the British Association, by J. Hopkinson, D.Sc., M.A., and published in the *Nautical Magazine*, contains the latest suggestions for improvement:

The increase in the number of light-houses has caused a difficulty in insuring that they shall not be confounded with each other. The existence of this difficulty is apparent from the defects of various expedients to which light-house engineers have reluctantly resorted to obtain necessary distinctions. In the most favorable circumstances, red glass absorbs nearly two-thirds of the light which would otherwise benefit the sailor. The use of color is thus an extravagant expedient, for an equally powerful white light could be produced with a much smaller consumption of oil. Still it has

been frequently necessary to employ red glass even in revolving lights. It must be a strong necessity which makes light-house boards consent to have the brightness of their lights so heavily taxed. The first French Light-house Commission definitely excluded colored lights from their scheme, but even France has had to give way. In an ideal scheme of lighting a coast, color would only be used for making particular directions from the light-house, as at Orme's Head, the Longships, and other places, but we should have no lights showing red, or alternately red and white, to all points of the compass. Another distinction which has found a great deal of favor is open, I think, to even graver objections than the one of color—the fixed and flashing light Here we have a light of the power of a fixed light during a greater portion of the time, but flashing out at stated intervals with the brightness of a revolving light. The essential *characteristic* of these lights lies in the combination of continuous light of a certain intensity, with flashes of a very much greater intensity. There must undoubtedly be circumstances of weather and distance in which the flashes alone can be seen, and the effect be similar to that of a revolving light, and be only distinguishable from it by the usually greater interval between the flashes. It is true the local knowledge of the seaman may remove the doubt, but on this the light-house engineer has no right to rely, and the fixed and flashing light remains open to the objection that in fair weather it appears as it is advertised to be, in foul it may simulate a revolving light, and may in extreme circumstances cause mistake and consequent disaster. The cost is that of a revolving light, but without its advantages. It is difficult to see why the ordinary intermittent light was not adopted instead of this dangerous combination.

Light-house optical apparatus may be broadly divided into two classes, the fixed, in which the light being condensed in altitude only, is sent simultaneously in all directions to the sea horizon; and the revolving, in which the lenses condense the rays in azimuth also, and as the apparatus revolves, cast powerful beams on the eye of the mariner at stated intervals, total darkness, with the exception of dim light scattered in the lantern, separating the beams of light. The former is open to one or two objections, the importance of which increases every year. There are no means of distinguishing one fixed light of the usual kind from another: as the demand for more frequent lights along the coast increases, this limits the use of fixed lights. On a very dark night, when the hulls and masts of vessels cannot be seen, there is some difficulty in distinguishing a distant fixed light from a nearer ship light or riding light. It has been urged as an objection to the now absolutely unnecessary increase in the power of ship lights, that they would thereby be liable to be confounded with light-houses. When visiting the Dungeness Light, I had the opportunity of observing the magnificent electric lights of the South Foreland, distant twenty-two miles, behind the lights of vessels riding at anchor near to, and I felt that I could not instantly and certainly distinguish one from the other. Doubtless, the experienced eye of a seaman would have instantly identified the light-houses, but perhaps the judgment of a landsman on the beach in a dark but clear night may be taken as a measure of that of a seaman on board ship in rough and rainy weather. For harbors, the fixed light is adopted in nine cases out of ten, and here an additional cause of trouble may arise to those unacquainted with the locality. Before the introduction of gas the harbor light was alone, and therefore unmistakeable; now it is sometimes almost lost amongst the gas lamps which illuminate the quay. Sir William Thomson has proposed to obviate these difficulties, whilst retaining the advantages of the fixed light, by improving the intermittent light, of which we have existing examples in Point Lynas, Anglesea, and other places, and diversifying it so that it might be applied to any or all of the fixed lights existing or to be constructed. His scheme may be best explained by reference to the light on the Holywood Bank, Belfast, which has been altered in accordance with his recommendations. This light is now distinguished by two short eclipses and one long, grouped together. The eclipses are produced by opaque shades revolv-

ing round the usual dioptric apparatus. The effect on the eye is as follows: bright 6½ seconds, dark ½ second, bright ½ second, dark, ½ second, bright ½ second, dark 1½ seconds, then again bright for 6½ seconds, the phenomenon repeating itself with a total period of 10 seconds. The three eclipses are easily described, and are instantly identified almost without thought. It is easy to see that the plan is as fertile as it is simple, and that it could furnish as many distinctions of fixed lights as can ever be wanted. Some difficulty was at first anticipated as to the possibility of adopting Sir William Thomson's proposal in the case of that important class of fixed lights in which certain bearings are marked by colored light, the colored light being made of equal power with the white by utilizing light which would otherwise be wasted on the land. But through these difficulties the way is now clear, and it may be safely asserted that there is no mechanical or optical difficulty in producing Sir William Thomson's eclipses in any case to which our light-house boards may think it expedient to apply them.

But revolving lights, in addition to their distinctiveness, have a recommendation in their great power. The use of red in revolving lights sufficiently proves that there is need for increasing the number of variations in this class. To meet this need I have designed forms of apparatus which give, instead of a *single* flash at stated intervals of 30 or 60 seconds, *two*, *three*, or, if required, *four* flashes in rapid succession, forming a group recurring at suitable intervals, such lights would naturally be named *double*, or *triple*-flash lights, or revolving lights with *double* or *triple*-flashes at intervals of 30 or 60 seconds, in contradistinction to the old revolving light, which would be distinguished as having a single flash. The apparatus is perfectly simple, and costs very little more than the ordinary revolving light. In the usual eight-sided light the rays are condensed into eight beams, the axis of which are at equal intervals of 45°. The double-flash light has twelve sides, giving twelve beams of light, but these are not spaced at equal intervals, but are grouped together in pairs, the axis of the lenses being alternately at intervals of 15° and 45°, if, then, the apparatus revolve in six minutes, as will be the case at the Little Basses, we shall have a powerful beam of light thrown to the eye, then a second of equal power, the two occupying about 22 seconds, then 38 seconds of darkness, to be followed by another group of beams of light. The triple-flash light is very similar, but has fifteen sides, five groups of three each.

There are several points of view from which the efficiency of a light may be judged, and it may be well to compare the new forms with the old in different aspects.

It is desirable that with a given consumption of oil the light should be as powerful as possible, or that no more oil than is absolutely necessary should be used to produce a light of a certain intensity. On the other hand, it is well that the light shall not be too long invisible, in fact, that it shall be seen for as many seconds as possible in each minute. These two conditions are exactly opposed, for as we condense more light into each beam by increasing the size of our lenses, we diminish the duration of brightness in comparison with that of eclipse. With a given illuminant, we may take as a measure of brightness sixty divided by the number of seconds the light is visible in each minute. Thus each panel of an eight-sided revolving light condenses light which would be dispersed over 45° of the horizon into about 4½°, it can thus be only seen during six seconds in every minute, and its power is ten times that of the corresponding fixed light. In Sir William Thomson's eclipsing system, the oscillations are so short that the light may be considered as continuously visible; they will also have the same power as the fixed light from which they are formed. They are in fact fixed lights furnished with distinguishing characters. The double and triple-flash lights on the other hand, are modified revolving lights. Let us compare the eight-sided revolving light, giving a flash every minute, with the double and triple-flash lights, giving respectively a group of two and three flashes every minute. The eight-sided light if it were white, would have a power of ten, taking the corresponding

fixed light as unity, but nearly two-thirds of this light is intercepted to make the light red. Its power will then be represented by a little less than four. The flash will also last but six seconds, and this will be the whole time for taking the bearing of the light until fifty-four more seconds have elapsed. In a double-flash light we have 30° condensed into 4½°, thus the intensity will be represented by 6⅔, whilst the distribution of the light and darkness will be very favorable, the individual flashes will last 4½ seconds, they will be separated by an eclipse of 10½ seconds, and there will be a long interval of forty seconds between the groups. The two flashes will be almost as convenient for taking a bearing as a continuous light lasting twenty seconds. Turning to the triple-flash light, we have a power of 5⅓, whilst the individual flashes will last nearly four seconds, and the group will occupy twenty-four seconds, giving an admirable opportunity of determining the direction of the light with such accuracy as the circumstances admit of. It may be said, generally, that the double and triple-flash lights rank next to the eight-sided revolving light in power, when the flashes of the latter are undimmed by the use of color, whilst they rank before all other revolving lights in the facilities they afford the mariner of making an accurate estimate of his position.

Perhaps the most important question which can be asked, regarding any new distinctive light which may be proposed is, Is it perfectly simple and easy to comprehend? Can it under any circumstances be mistaken for some other form of light? At first sight it would appear that both plans here described are opened to the charge of complication; but a moment's consideration shows that this is not the case. It is easier to recognize a group of two or three flashes from a single one, or to distinguish between groups of three eclipses—say, "short, long, short," from "short, short, long," than to ascertain certainly the period of a revolving light. Again, it may be urged as an objection to groups of flashes that some circumstances may cause the observer to miss one flash in the group and mistake a double for a single, or a triple for a double-flash light. Again, I appeal to time-honored experience. It is conceivable that by the obliteration of a flash a half-minute light may be taken for one having a double period. If such a mistake occurred, it would be longer before it could be rectified than in the case of the double-flash light; but I am not aware that any such inconvenience is actually felt.

The advantage lies wholly with the new lights; a group of three flashes or eclipses would be recognized without hesitation by a savage who was utterly ignorant of any means of measuring time, whilst the difference between thirty seconds and a minute would be without meaning to him. There is no complaint, nor cause for complaint, of the best revolving lights on the score of simplicity, and certainly still less will there be in the new combination.

It is worthy of notice that, if a coast were lit on a system based on a use of grouped flashes, or grouped eclipses, with the appearance of the light could be made to correspond the blasts of the fog-horn; a group of three flashes, at intervals of thirty seconds, would naturally be used in conjunction with a fog-signal sounded three times in succession at the same interval.

Maj. Elliot's experience in connection with the trials of fog-signals at Dover is thus related:

On the 19th of May I proceeded to Dover, to be present at the commencement of an extensive series of fog-signal experiments, to be undertaken by the Trinity House, under the supervision of their scientific adviser, Professor Tyndall.

There were present on this occasion, besides Professor Tyndall, several of the Elder Brethren, the Engineer of the Trinity House, a representative from the Board of Trade, and the Inspector of Irish lights.

The experimenters divided themselves into two parties, and embarked on two steam-yachts, for the purpose of practically testing the sounds while afloat.

The limited time at my disposal did not allow me the pleasure of accepting an invitation to join them, and I had only an opportunity of observing the machines themselves at the experimental station at South Foreland. This I did be-

fore inspecting the South Foreland light-houses to which I at once proceeded.

There were two sets of signals used; one placed on the summit of the cliff near the engine-house belonging to the light-station, at an elevation of 275 feet above the sea; the other near the foot of the cliff, at an elevation of 40 feet, and near the bottom of an old shaft, by which it was reached from the upper station.

The machines used were steam whistles, air whistles and fog trumpets. The trumpets and the air whistles were connected with two air chambers, supplied with air by pumps driven by the engine used for the electric lights.

An Ericsson engine was at the station, but was not used.

The steam whistles were supplied by a twenty horse-power upright engine.

The trumpets were shaped like those used in our own service. The steam whistles, with a diameter of 12 inches, had a height of 14 inches, the space between the lip and the disk being $1\frac{7}{8}$ inches. The air whistles, with a diameter of 6 inches, were $9\frac{1}{2}$ inches high, the lips being placed $1\frac{1}{2}$ inches from the disks.

The steam whistles were blown under a pressure of 64 pounds; the air trumpets and whistles under a pressure of 18 pounds. Behind these latter were reflectors about 12 by 15 feet, slightly curved toward the land.

The day was stormy, there being a high wind from the eastward accompanied by rain, and the Strait of Dover was pretty rough, but on the whole the weather was favorable for the purpose. The two parties continued afloat all day, and the signals were sounded until dark.

On shore, so near the signals, and while inspecting the light-houses, I could not determine in regard to the qualities of the different sounds as well as could those on board the yachts, but, so far as I could judge, the air whistles and trumpets were decidedly superior to the steam (12-inch) whistles. The note of the latter was much more shrill than that found by us to best serve the purpose for which this instrument is designed, and the condensation of the steam, and consequent drip of water were so great, I was convinced, as to greatly impair the vibration.

The results of the trial of the 12-inch steam whistle were from some cause much less satisfactory than in our experiments at Portland, and at our light stations, the sound produced being certainly no louder than that of the 6-inch air whistle.

On the return of the experimental parties in the evening, there was a general expression of disappointment in regard to all the signals.

It was stated that the yachts ran outside the limits of sound at comparatively short distances; that the air trumpets and whistles were heard much farther than the steam whistles, while a gun fired at Dover Castle was heard at much greater distance than any of the signals at the station.

The yachts were out in the channel occupying various positions in relation to the wind, and the signals were regularly sounded according to a programme previously arranged.

The experiments, in which were afterward included one of our own whistles and sirens, were to be continued for some months. Following will be found a list of the printed questions to be considered and answered by the experimenters:

"SOUTH FORELAND FOG-SIGNAL EXPERIMENTS—QUESTIONS PROPOSED TO BE DETERMINED.

"First. What is the most efficient height above the sea surface for the signals?

"Second. What are the comparative values of air and steam for sounding whistles and horns?

"Third. Which is the more efficient instrument—whistle or horn?

"Fourth. What is the proper pressure, having regard to efficiency and economy, at which air or steam should be employed for whistles or horns?

"Fifth. What is the relative range of the same whistle or horn with various pressures of steam or air?

"Sixth. What is the relative range of long and short blasts from the same instrument, and what is the minimum duration of the blasts of maximum efficiency?

"Seventh. What is the most efficient note for a fog-signal?

"Eighth. What is the relative range

of the highest and lowest notes of the same instrument?

"Ninth. What is the relative range of one and two whistles or horns of the same power?

"Tenth. What is the relative range of the horn in the direction of its axis, and at 45° and 90° respectively from the direction of its axis?

"Eleventh. Is the horn used with maximum efficiency by always keeping it pointed to windward, by using more than one horn and distributing the sound over the phonic arcs or by rotating one horn?

"Twelfth. Is any appreciable advantage gained by using reflectors in conjunction with whistles or horns; and, if so, what shape is preferable?

"Thirteenth. What horse-power is required to sound the most efficient signal (whistle or trumpet) for giving an effective range (of two miles) in fog and against wind at force 9 of the Beaufort scale?

"Fourteenth. How is the propagation and distribution of sound affected by different atmospheric conditions?"

It has been found by General Duane, of the Corps of Engineers United States Army, and light-house engineer of the New England coast, in his experiments made to determine the best form of boilers for steam fog-signals, that, as the steam used is at a high pressure, and is drawn off at intervals, and there is a consequent tendency to foam and to throw out water with the steam, a horizontal tubular boiler (locomotive) with rather more than one-half of the interior space allowed for steam-room, is best adapted for the purpose.

The steam-dome must be very large and be surmounted by a steam-pipe 12 inches in diameter. Both dome and pipe were first made small, and were gradually enlarged until no difficulty with regard to foaming remained.

The steam should be drawn off at a point 10 feet above the water-level in the boiler.

The main points, therefore, to be observed in regard to the *boiler*, are to have plenty of steam-room and to draw the steam from a point high above the water-level.

In regard to the *bell of the whistle*, the best results have been obtained by making the diameter two-thirds of its length, and the "set" of the bell, *i. e.*, the vertical distance of the lower edge above the cup, from one-fourth to one-third of the diameter for a pressure of steam of from 50 to 60 pounds.

These conditions were not fulfilled in the Dover experiments at the time of my visit, and I have no doubt that this accounts is some measure for the disappointing results of the trials with the steam-whistle.

ON THE PNEUMATIC TRANSMISSION OF TELEGRAMS.*

From "The Engineer."

THERE are twenty-four pneumatic tubes in London, of an aggregate length of seventeen miles 1,160 yards, four tubes in Liverpool, three in Dublin, five in Manchester, three in Birmingham, and one in Glasgow. When the number of tubes became large, it was fonnd necessary to simplify the valves and sluices, rendering them less automatic, but easier to keep in order, than the earlier apparatus. Lead was preferred to iron as the material for the tubes. An experience of twenty-one years had shown that with felt message holders, or carriers, there was no abrasion of the metal, which became highly polished, and that the tubes were practically air-tight, the exhaustion in one, 1,289 yards in length, occupying thirteen minutes in falling from 17.25 in. of mercury to atmospheric pressure, including the leakage from the valves. Iron had been used for two tubes, each 2,610 yards long, but it was found to rust rapidly, and to wear out the carriers. In the Paris system the iron tubes did not rust, and it was suggested that the difference was due to the

* A paper read before the Institution of Civil Engineers by R. S. Culley.

air in Paris being carefully cooled by water, and to the friction of the heavy carriers of iron covered with leather; while the air in London was used warm from the pumps, and the carriers are made as light as possible. The diameter adopted for the tubes is 2¼ in., as being large enough to carry the traffic with sufficient speed, and not so large as to require a costly volume of air. The carriers are cylindrical boxes of guttapercha, covered with shrunk drugget; their weight was 2¾ ounces. The traffic is regulated by electric signals. Stoppages are rare, and are cleared by filling the tubes with water and applying pressure. It has never been necessary to open a lead tube, except in cases of bad construction, or of external injury caused by workmen.

On the Continent, with perhaps an exception as regarded the Paris Bourse, trains of carriers were run at fixed times, in Paris every quarter of an hour; but in England a message was never delayed —speed was the first requisite, and carriers followed one another as rapidly as possible. An opinion expressed during a former discussion of the subject, that pneumatic was more costly than electric transmission, was shown to be erroneous; for the total expense of the former in London was barely two-thirds of the amount which would have been required to pay the salaries alone of the clerks needed under the latter, irrespective of the cost of wires and instruments.

Experiments showed that the speed of a carrier driven by compressed air was greater when the pressure was cut off after each transit; or, in other words, that there was a loss of speed when the air was kept constantly in motion. In the former case the carrier started into a comparative vacuum at atmospheric pressure; in the latter case into dense air; consequently the higher the pressure employed, the greater the difference in speed—with 14 lb. pressure the difference was 6 per cent. In working by vacuum a reverse result obtained. The experiments likewise demonstrated that the pressure fell to zero at the distant end and almost regularly with the length, but not quite so. With an initial pressure equal to 18 in. of mercury the pressure at the end of a tube 8454 ft. long was 9.75 in. instead of 9 in., and in every case there had been a higher pressure at intermediate points than that due to their position, when the fall of pressure was represented by a straight line. This result was attributed partly to the inertia of the air, partly to friction. The experiments also showed that when compressed air was admitted into a long tube, or the air was pumped out of it, a sensible time elapsed before the permanent condition of the air pressure was established. In a tube 5523ft. long this interval was forty-five seconds for the end next the air-pump, and about seventy-five seconds for the centre of the tube. The temperature of the air issuing from a tube was not lowered to an extent corresponding with its expansion in the tube, because it gained heat from the soil in London; but in Berlin, where the tubes were bedded in dry sand, the theoretical temperature was more nearly attained. Comparing a 3 in. tube with a 2¼ in. it was shown that more than double engine power gave only 16 per cent. higher speed in the larger tube, so that any increase of diameter above that actually necessary to carry the traffic in the required time was attended with unnecessary expenditure. Again, by doubling the pressure only 30 per cent. in time was saved, but thrice the engine power was needed. In two tubes, each 1000 yards long, one 3 in. and the other 2¼ in. in diameter, by working the larger with a pressure of 5 lb. and the smaller with one of 7 lb. the transit was made in nearly equal times, while the engine powers were 2.6 horse-power and 2.1 horse-power respectively. The smaller tube at the higher pressure was therefore the most economical. The tubes should in consequence be as small as possible. The relative economy of working by vacuum, or by pressure, was then considered, to determine at which end of a tube, required for traffic in one direction only, the engine should be placed. It would at first sight appear that vacuum would be less expensive, because there was less weight of air to move than when using pressure. But as the rarefied air gained heat from the tube as it passed along, the volume which must be removed by the pump was greater than it would otherwise be; so that practically the cost of the two systems was the same.

THE EFFECT OF DEAD SPACE IN WOOLF ENGINES.

By O. HOLLAUER.

Translated from Bulletin de la Soc. Indust. de Mullhouse.

II.

The internal heat increases continually during eighteen-twentieths of the course; on the other hand, the diagram itself gives as the work of the period of compression 77 k. × 81 m. ; hence

$$AF = \frac{77.81}{425} = 0.18 \text{ c.}$$

a small amount of heat ; proving that almost the total increase of internal heat

$$U_n - U_0 = 46.53 - 41,47 = 5,06 \text{ c.}$$

is due to the action of the walls alone. These being up to this time warmer than the enclosed steam, evaporate the water that coats them. We shall see that the reverse might happen.

Finally, at eighteen-twentieths of the course the interior return stroke of the small slide closes up escape, and leaves between the two distributing chests 0,890 c. m. of steam at 0,993 k. pressure, and containing 15.7 per cent. of liquid water. The weight of this mixture is 0,0890 c. m. × 0,58271 = 0,0518 of steam, and $0{,}518 \text{ k.} \times \frac{0{,}0141 \text{ k.}}{0{,}0757 \text{ k.}} = 0{,}0097$ k. of water; making a total of 0,0615 k., of which the internal heat U = 0,0518 k. × 496,78 c. + 0,0615 k. × 99.37 c. = 31.84 c.

The rest of the 0,0898 in the small cylinder containing 0,0757 k. − 0,0518 k. = 0,0239 k. of steam, and 0,0141 k. − 0,0097 k. = 0,0044 k. of water ; total, 0,0283 k. of which the internal heat U = 46,53 c. − 31,84 c. = 14,69 c., continues to condense, and finally fills 0,0110 c. m. at a pressure of 2,016 k. In this condition the steam goes to mingle with that from the boiler. It contains 0,0110 c. m. × 1.1332 k. = 0,0125 k. of steam, and

0,0283 k. − 0,0125 k. = 0,0158 of water,

or 55,53 per cent. Its internal heat

$$U = 0{,}0125 \text{ k.} \times 480{,}24 \text{ c.} + 0{,}0283 \text{ k.} \times 120{,}60 \text{ c.} = 9{,}41 \text{ c.}$$

The mixture 0,0283 k. has lost during this period of compression in the interior of the small cylinder

$$U_0 - U_n = 14{,}69 \text{ c.} - 9{,}41 \text{ c.} = 5{,}28 \text{ c.} ;$$

the condensation is

55,83 per cent. − 15,70 per cent. = 40,13 per cent.

This result of experiment, apparently paradoxical and contrary to the teaching of theory, is confirmed for the nineteen-twentieths remaining of the course, when the pressure 1,326 k. gives a weight of steam,

0,0259 k. × 0,76548 k. = 0,0198 k. ;

and of water,

0,0283 k. − 0,0198 k. = 0,0085 k.,

or 30 per cent., whose internal heat

$$U = 0{,}0198 \text{ k.} \times 490{,}28 \text{ c.} + 0{,}0283 \text{ k.} \times 107{,}70 \text{ c.} = 12{,}75 \text{ c.}$$

an amount less than 14,69 c., which existed at the moment when the small slide cut off the escape.

So, notwithstanding the work of compression, the steam confined in the small cylinder condenses after the slide has separated it from that which fills the dead space between the two organs of distribution ; and the loss of heat is still due to the action of the walls which have been colder than the steam during this last period of rapid compression.

Now that we know the different weights, both of steam and water, which remain in the dead spaces and the consequent transformations, we can study the action that takes place in the same motor in case of compression or non-compression of steam in the dead spaces.

The weight of the mixture of steam and water, which leaves the boiler and traverses the cylinders at each stroke of the piston is

0,6956, being 0,6678 k. of steam and 0,0278 k. of water ; carrying with it a total heat

$$0.^{k}6678\ \beta + 0.^{k}0278\ q = 0{,}6678 \times 651{,}17 \text{ c.} + 0{,}078 \times 147{,}83 \text{ c.} = 438{,}96 \text{ c.}$$

This weight coming to the small cylin-

der is mixed with that which remains after compression, that is: 0,0125 k. of steam and 0,0158 of water at a pressure of 2,016 k., having a total heat

$$0.^{k}0125\ \beta + 0.^{k}0158\ q = 0{,}0125 \times 643{,}04\text{ c.} + 0{,}0158 \times 120{,}60\text{ c.} = 9{,}93\text{ c.}$$

When the discharge from the small into the large cylinder opens, the steam again encounters in the dead space between the two slides, steam of weight 0,0518 k. and water of weight 0,0097 k. which have been left there after compression, containing a total heat

$$0.^{k}0518\ \beta + 0.^{k}0097\ q = 0{,}0518 \times 636{,}66\text{ c.} + 0{,}0097 \times 99{,}37\text{ c.} = 33{,}94\text{ c.}$$

In the large cylinder we find the 0,0223 k. of steam, supposed dry, that remains after the escape into the condenser, of which the total heat is

$$0k{,}0223\beta = 0{,}0223\text{ k.} \times 623{,}67\text{ c.} = 13{,}91\text{ c.}$$

The values of the work per stroke were obtained by measuring the diagram curve surface with the planimeter.

With compression.

Work on the small piston,	10266 k. × m.
" " large "	12307 "
Work negative of counter pressure	3992 "
Total absolute work, F =	26565 k. × m.

Without compression.

Work on the small piston..	10565 k. × m.
" " large " ..	12475 "
Work on the negative of counter pressure.....	3982 "
Total absolute work, F′ =	27022 "

But to produce this work it was necessary to furnish of heat in the first case:

For the steam traversing the cylinders.....	438,96 c.
For that which traverses the jacket.....	48,77 c.
Total C =	487,73 c.

Consumption for absolute work F = 26565 per H. P. per hour

$$\frac{C \times 27000}{F} = 4957.2\text{ c.}$$

and of dry saturated steam

$$\frac{4957.2}{651.17} = 7{,}6127\text{ k.}$$

In the second case, supposing that there has not been compression in the dead spaces, there must be furnished besides the heat due to the steam which traverses the cylinders and the jacket 487,23 c.

There would be	
In the dead space of the small cylinder.....	9,23 c.
In the space between the slides.	33,94
In the large cylinder.....	13,91
Total C′ =	545,51 c.

Consumed to produce an absolute work F′ = 27022 k. × m., or per H. P. hourly,

$$\frac{C' \times 270000}{F'} = 5450{,}6\text{ c.}$$

and of dry saturated steam,

$$\frac{5450{,}6}{651{,}17} = 8{,}3705\text{ k.}$$

If then this engine had worked without compression it would have consumed at least 9,95 per cent. more than with compression; yet this compression is not pushed very far, and is easily attained in practice by proper management of the slides.

ENGINES WITH A SINGLE CYLINDER.

The analysis of this kind of motors with regard to dead space, if not impossible, is difficult.

Suppose that discharge into the condenser is stopped at four-fifths of the stroke. From this time there is confined in the cylinder undergoing compression during one-fifth of the stroke, a certain weight of mixed steam and water.

We say a mixture; for this steam is moist at the moment of closing the slide; examination having shown (even in the case of engines with steam jackets) that at the end of cut off there still remains 10 to 15 per cent. of water, mostly upon the walls; that during the discharge into the condenser a part, not all, of this water evaporates to give place to the cooling by the condenser.

In the Woolf engine during the period of expansion the *known* weight of mixture is between the two pistons; so that its constituents may be evaluated for

each point of the course. At the moment when the large slide cuts off communication with the small cylinder causing compression, the pressure indicated on the diagram gives the density and the weight of the volume of dry saturated steam, the residue being water.

This is not the case with single cylinder engines, in which all the steam compressed has been in direct communication with the condenser. A part of the 15 per cent. of water which it holds at the end of the expansion is evaporated upon the walls; the residue passes to the condenser in the condition of water; but how much remains in the cylinder at the moment when the slide has just closed?

Diagrams taken with Watt's indicator may, as with Woolf's engine, give the weight of dry saturated steam corresponding to the pressures at various points of the stroke. If the weights diminish we may affirm that there is condensation during compression; but in the contrary case, there may also have been some evaporation, which superheats the steam if little water remains in the cylinder. In either case one or the other of the phenomena must have taken place; for it is indispensable to know the weight of water remaining in the cylinders at the moment of closing in order to determine the internal heat of the mixture, the only value which determines of the transformation of the entire mass.

As soon as the slide opens the escape into the condenser, the steam is precipitated into it, and there immediately ensues upon the walls of the cylinder a very rapid evaporation of the coat of water which covers them. This phenomenon, identical with that observed in steam generators where a more rapid evaporation takes place every time that the motor uses a certain quantity of steam, carries along a quantity of water. We, therefore, naturally employ Hirn's calorimetric method, which has furnished us with satisfactory results when applied to steam generators.

But the process differs with the two kinds of engines; one in which the steam escapes freely into the air; the other, in which it passes into the cylinder. In the first case, the difficulty is no greater than when we operate upon the boilers themselves; provided that the pressure in the escape pipe is sufficient to cause discharge into the calorimeter. Otherwise we have recourse to a modification. At the extremity of the worm, a copper reservoir is soldered of about a litre capacity, in which a vacuum is made by introducing 250 grammes of water, and bringing to boiling point, so that the air is expelled. It is then cooled, when the stop-cock has been closed. The calorimeter being mounted, the reservoir and the worm are plunged into the cold water and the whole is weighed. Then the apparatus is brought near the escape pipe and filled, and the steam is allowed to flow slowly in and condense. When the water of the calorimeter is sufficiently heated, the stop-cock must be closed and the apparatus detached so as to weigh again, which gives the weight of condensed steam.

The initial and final temperatures of the cold water as well as the pressure are registered; consequently the temperature of the escape steam in the cylinder. We have then all the elements necessary to determine the amount of water carried by the steam, which is in some cases quite considerable.

The method employed for condensing engines is an application of a general method by Hirn (*Bulletin*, Oct., 1869). We give the results of two experiments made by us with Hirn upon an engine with and without superheating. The steam consumed was directly measured during an entire day; as was the water of condensation and its heat.

ENGINE WORKING WITH SUPERHEATED AT 231°; 143,78 IND. H. P.

The heat in the condenser per stroke of piston is 175,46 c., and the final temperature of the water of condensation $t'=30°,50$; the weight of steam consumed is 0,3065 k. per stroke; the mean counter pressure under the piston during escape to the condenser is $P_0=0,368$ k. per square centimeter; giving a temperature of steam $T=73°,49$; and we have

$\beta=628,91$ c.; $q=73,72$ c.; $r=555,19$ c.

The water carried by the steam is

$$m=\frac{0,3065\ (628,91-30,50)-175,46}{555,19}$$

$=0,0143$ k. or 4,67 per cent.

ENGINE WORKING WITH MOIST STEAM; 136,46 IND. H. P.

The heat in condenser per stroke is 201,50c.; the final temperature $t=32°,65$; steam consumed = 0,3762 k.; counter pressure $P_o=0,367$ k.

$T=73°,42$: $\beta=628,89$ c.; $q=73,65$ c.; $r=555,24$ c.

$$m=\frac{0,3762\ (628,80-32,65)-201,50}{555,24}$$

$=0,04106$ k. or 10,91 per cent.

For first engine:

Steam = 0,27035 k.; water=0,03615 k.; or 11,80 per cent.

For second engine:

Steam=0,2813 k.; water=0,0949 k.; or 25,23 per cent.

In the first case we have 4 per cent. of water carried by the escape steam; in the second, 10,91 per cent. It follows that 11,80−4,67=7,13 per cent. in the first engine were evaporated upon the walls, and in the second 25,23−10,91=14,32 per cent.; just twice as much; as is also the case of engines with and without steam jackets.

It has been shown how in case of condensing engines the weight of water that passes directly to the condenser is determined, knowing that the steam is moist and the proportion of water it contains; suppose that the escape is cut off at four-fifths of the course; it is then easy to determine the value of the internal heat of the mixture remaining in the cylinder and to follow the variations during the period of compression. It is necessary to experiment upon an engine with a single cylinder, so as to be able to regulate the compression, which can almost always be done with engines having four slides or valves, where the movement of distribution is independent of that of admission.

Further experiments will probably confirm the new theory of Zeuner; that the compression in the dead spaces in an ordinary engine, if pushed to the point of initial pressure, annuls the effect of dead space. The engine then acts as one without dead space, the escape going on during the entire stroke of the piston. We congratulate ourselves upon being the first to give experimental proof of this principle, so important in practice in view of the fact that Woolf's engine realizes an economy of 10 per cent.

RAIN WATER IMPURITIES—THE RIVERS POLLUTION COMMISSION.

From "The Engineer."

THE second part of the last report of the Rivers Pollution Commissioners relates to the classification and chemical composition of the potable waters of Great Britain. Six different kinds of water are specified, the first being rain water. In illustration of this part of the subject there is an excellent hydrographical map of the British Isles, prepared for the Royal Commission under the superintendence of Mr. G. J. Symons. Different tints of color indicate the difference in the amount of the annual rainfall in the various parts of the United Kingdom. The greater the rainfall, the deeper the tint, and a glance of the eye at once detects where the heaviest fall takes place. Beginning with the highest figure on the scale, namely, above 75 in., the most southern point is at the summit of the Devonian range, in the region of Dartmoor Forest. Traveling northward the next instance of the kind is round about Plynlimmon. Both these rain areas are oval spots, the first about eleven miles and the second about fifteen in length, by six or seven miles in width. The Dartmoor ellipse is surrounded by an annulus, or zone, about four miles across, where the rainfall is less than 75 in. and not less than 50 in. A patch where the rainfall is from 50 in. to 75 in. occurs on the mountain range west of the Tamar, where the hills culminate in a point of great elevation. Reverting to the mountains of Wales, we observe a

patch of the maximum tint, not quite forty miles long, extending south-east from Snowdon. All down the Cambrian range, and southward over the high hills north of Merthyr Tydfil, there appears the tint which corresponds to the second gradation of rainfall, namely, from 50 in. to 75 in. From the centre of the Snowdon area, drawing a line across the country to Liverpool, it is singular how rapidly the rainfall decreases. For only three or four miles we have the second gradation, and we then enter on a strip scarcely nine miles wide, where the rainfall is from 40 in. to 50 in.; a still narrower tract has from 30 in. to 40 in. of rain. Over a yet narrower width the fall is from 25 in. to 30 in., and then to the south-west of the Dee there is a slip of about eight miles in breadth, where the fall is as low as anywhere on the map, namely, less than 25 in. From the verge of the greatest rainfall to the verge of the least is thus about twenty-five miles. Starting from a point a little northward of the centre of the Snowdon area, we travel over the scale even somewhat quicker. At Liverpool the rainfall increases again, being 35 in. per annum.

It might be thought strange that we have not yet mentioned the Irish rainfall; but the fact is, that no part of Ireland seems to have a rainfall exceeding 75 in. An area of about 35 miles square round about the Lakes of Killarney has from 50 in. to 75 in., and a small patch at Valencia has from 50 in. to 60 in. With these exceptions, the rainfall along the whole western and southern coast of Ireland has a range of between 40 in. to 50 in. South of Belfast, about Dundrum Bay, the scale sinks to 25 in. or 30 in. The remainder of the Sister Isle, taking the eastern side, excepting the south-east, and including all the centre, has a depth of rain between 30 in. and 40. On the Blackwater and the Lee this low scale comes to withih twelve miles of the Killarney area. The area of this moderate rainfall also stretches westward towards Galway Bay, until its distance from the sea is little more than ten miles.

Returning to Great Britain, we have to proceed to the Cambrian group, in order to find a rainfall exceeding 75 in. Here Helvellyn occupies the centre, and the longer axis of the ellipse runs from east to west for about 25 miles. Skiddaw and Sca Fell are pretty nearly on the extremities of the shorter axis. A zone of between 50 in. and 75 in. of rainfall surrounds this wetter portion, and also sends off a lobe to the south-east. Two areas of this second gradation, north of the Solway Firth, point us to the Scotch mountains where the Dee and the Nith find their head waters. Perhaps we ought to have mentioned, in regard to Wales, that the centre of the Isle of Anglesey has a patch—a very small one—of this kind. In this map Scotland is famous for a long, dark patch, showing a rainfall exceeding 75 in., all the way from the Firth of Clyde, across Ben Nevis, into the county of Ross. Altogether, this tract of country is 100 miles in length, with an average of fully 20 miles in breadth. An equal depth of rainfall shows itself in a small area to the westward, reaching from the Isle of Mull nearly across the mainland on the north. The Isle of Skye has another of these maximum patches, and furnishes the most westerly example of this heavy rainfall in the kingdom. The rainfall in the Isle of Lewis is between 40 in. and 50 in.

Along the extreme south of England, not going further north than Guildford, and taking a line from Ilfracombe to Ashford, there is a tract of country where the rainfall is from 30 in to 40 in. From Portsmouth, along the immediate vicinity of the coast to Dovel, and very nearly to Ramsgate, is an area where the fall is from 25 in. to 30 in. This area also sweeps round to the north of the one previously described, but keeps to the south of London. It touches the estuary of the Severn, whence it is driven somewhat southward by the heavier rainfall of the Mendips, and then goes off to the north round the base of the Cotswold Hills, travelling north-west to Liverpool Bay, and due north by a narrow strip through England to the Firth of Forth, reappearing at the Moray Firth. It also possesses a patch of considerable extent along the Yorkshire Wolds, and another one to the north-west of London, apparently due to the Chiltern Hills. Finally we come to the area of least rainfall—namely, less than 25 in. This may be described as

starting from the North Foreland, Dartford, and Reading, and sweeping away all up the eastern part of England to Sunderland, reaching laterally from the German Ocean to Buckingham, Nottingham Leeds, and Stockton-on-Tees. As it goes through Yorkshire it has a very wet region near at hand on the west. There are also the Chiltern patch in the south and the area of the Wolds in Yorkshire. The Royal Commissioners make no detailed allusion to the hydrographical map in their report, but certainly it is by no means the least interesting feature in the volume. A contour map of this kind would be especially valuable, as immediately showing the effect of elevation on rainfall.

Rain is no sooner discharged from the clouds than it begins to undergo pollution. The "freshness" of the air after a sharp shower indicates the nature of the process which has been going on. The falling drops have been literally "washing" the atmosphere, carrying down with them the floating particles of dust, and absorbing certain gaseous matters. Near the sea, in particular directions of the wind, the rain-drops become impregnated with a certain portion of salt. In the neighborhood of alkali works the rain will be sometimes acid. In order to obtain rain water in a fair degree of purity, the Commissioners caused a leaden rain collector, the thousandth part of an acre in extent, to be erected in the middle of an arable field on Mr. Lawes' experimental farm at Rothamsted, near St. Albans, twenty-five miles from London, and 420 ft. above sea-level. In several cases the rain water thus collected exhibited on analysis a degree of pollution which could only be occasioned by some accidental cause. The only samples really to be relied upon are those which were collected under personal supervision. These samples, fifteen in number out of the total seventy-one, were much less contaminated with organic matter as compared with most of the others. Still, it was found that even this specially collected rain water contained more organic polluting matter than that which appertained to sundry springs and deep wells. The superior purity of the latter waters is attributed to "exhaustive treatment by natural intermittent filtration." In the best samples of rain water the organic elements averaged 081 in 100,000 parts. Deep well waters in the new red sandstone had only 050 parts, in the oolites 047, and in the chalk 067. Spring waters from granite and gneiss rocks had 050 parts, from silurian rocks 065, from Devonian rocks and old red sandstone 066, and other examples might be cited.

The total solid impurity in the rain falling at Rothamsted, in the best samples, averaged 2.97 parts in 100,000 of water. The quantity varied materially with the direction of the wind, the south-west wind bringing the greatest quantity, and the north-west the least. The wind had less effect on the proportion of organic impurity than might have been expected. Nevertheless, when the wind blew from points between south-east and north-east, it delivered rain more highly charged with organic impurity than when coming from any other quarter. The average proportion of "mineral nitrogen" also varied with the wind, being highest when the wind was south-east, a direction which rendered it liable for the rain-clouds to pass over London before reaching Rothamsted. The south-west wind deposited rain which did not contain one-third as much nitrogen as that which came from the sout-east. Chlorides were most distinctly present when the wind blew from the north-east, coming from the centre of the German Ocean. The rain from the south-east had only one-thirteenth as much chlorine as that from the north-east. A sample of rain water collected by the Commissioners at a height of about 100 ft. above the sea at Land's End, when a strong wind was blowing from the south-west, contained no less than 21.8 parts of chlorine in 100,000. The hardness of rain-water ranges from zero to 10 degrees. But the higher degrees in this range are due to strong winds from the sea along the coast-line. At Rothamsted, in the whole seventy-one samples, the hardness never exceeded 1.7 deg., and averaged only 0.49 deg.

Dew and hoar frost are less pure than rain, a result which accrues from the circumstance that these forms of water are condensed out of the stratum of the atmosphere which is nearest to the earth's surface, where impurities are

more prevalent than in higher regions. The average of the organic elements per 100,000 in the samples of dew and hoar frost in the leaden collector at Rothamsted was 0.34, whereas the average in the entire seventy-one samples of rain was only 0.116. A large proportion of ammonia was also found in the dew and hoar frost, the average being as high as 0.198, whereas the average of ammonia from all the rain-water samples was only 0.050. The excess in the dew and hoar frost is attributed to the continuous evolution of ammonia from the manured land, and the presence of putrescent animal matter near the surface of the earth. The leaden collector, we should observe, was raised 2 ft. above the ground.

One sample of rain water was collected at Lancaster-gate, Hyde Park, on a day in November. The organic elements were 0.423, and the ammonia 0.210. The chlorine was 0.50, and the hardness —entirely permanent—was 1.1 deg.

It thus appears that rain water, fresh from the clouds, is not so uniformly free from impurities as is commonly supposed. The Commissioners tell us that rain is in reality "water which has washed a more or less dirty atmosphere." It is described as "laden with mineral and excrementitious dust, zymotic germs, and the products of animal and vegetable decay and putrefaction." A tumbler of rain water, taken as the liquid falls to the earth, contains as much impurity as a man would inhale from the atmosphere in eight days. Few people have been aware that heaven threw so much dirty water in their faces. It is not the sky, but the earth, that gives us pure water. The clouds gives us a modified kind of sewage, and the morning dew is anything but nice stuff to wash with, much less to drink. Some of the Rothamsted rain water contained arsenic, and in other instances there were traces of phosphoric acid. The fact is that the rain has to undergo the process of intermittent downward filtration through the earth's strata before it is fit to drink. The Royal Commissioners tell us that in Great Britain, and more especially in England, we shall "look in vain to the atmosphere for a supply of water pure enough for dietetic purposes." Impure at first, rain water becomes far more so after washing the slates, tiles, or thatch of a dwelling, and running into a tub or tank. "Briggs's soft-water cistern, Brook Hill, Greaseley, Notts, June, 1871," had 126 parts of solid impurity in 100,000; while the pervious sewage or animal contamination ran as high as 84.1790, with 11.50 of chlorine, and 55.7 degrees of hardness, of which 51.5 were permanent. Altogether, this delicious "soft" stuff was a good deal stronger than average London sewage. Of eight samples of rain water stored for domestic use, only one was fit for its destined purpose. Five of the eight were "very badly polluted," one of the worst being obtained, from a tank at Sheffield barracks. It is, however, a fact to be noted, that the rain water from a tank near Spalding, although unfiltered, gave no indication of previous animal contamination.

THE NEW BEIRUT WATER WORKS.

By JOHN C. HURD, Esq.

Written for Van Nostrand's Magazine.

The prospect that some great political change will soon occur in the lands bordering the Eastern Mediterranean, makes it likely that particular interest may soon be freshly awakened in respect to many localities which are ordinarily remembered only in their connexion with ancient and mediæval history. The capacity of Palestine and Syria to become the peaceful scenes of modern commercial and industrial energy, as they have been for centuries the sacred battle fields for successive invaders, of various race, faith and civilization, may then become matter for practical valuations.

Already, for some years past, one city in Syria, Beirut, has been experiencing a renewed growth and a remarkable development in material progress. When, in 1831, under Mohammed Ali, Beirut,

was made the quarantine station for Syria, and, indeed, its capital city, the population was about five thousand, when Mr. Thomson, in 1860, wrote his well known work "The Land and the Book," he thought it had risen to about forty thousand; and it is now estimated to be nearly one hundred thousand, of whom probably not more than one-fourth are Moslems. Very little is known of the earlier history of the place, and the city is not named in any Biblical narrative. It has, however, been an important place at various distinct periods: probably, even under the Phenicians, and certainly under the Greek empire of Alexander's successors, and under the Romans. It was deemed the most beautiful and salubrious locality at the head of the Levant. It enjoyed the privileges of a Roman colony in the time of Augustus. When Herod Agrippa, otherwise known as Agrippa the Great, held Syria and Judæa with almost royal authority, under the Emperor Claudius in A. D. 41, he adorned the city with numerous public buildings in the grandly luxurious style characterizing the Imperial administration. This magnificence was almost obliterated by the earthquakes which, in the reign of Justinian, desolated many cities in the Eastern portions of the Empire. Some of the granite columns may still be seen beneath the waters of the harbor, and others incorporated into the modern mole or breakwater.

We may assume that Roman architects would nowhere omit provision for baths and fountains. There are still existing within the city several remarkable wells pierced into the rock; one, it is said, being one hundred and fifty feet in depth. The name of the city, indeed, is thought to have been derived from the word *beer*, signifying a well of water, in the Semitic languages. A canal was cut by Djerra Pacha to bring water from the small stream nearest the city called Nahr Beirut, River of Beirut. But the care of the ancient rulers for a copious supply of water is attested by the remains of a great canal aqueduct, now dilapidated as to the part nearest the town by its having within a recent period been demolished to afford ordinary building material. Mr. Thomson thought that, before this took place, this aqueduct might, at a moderate expense, have been made to serve its original purpose. Its length was twenty miles, and its starting point in the Lebanon was two thousand feet above sea level. Where it crosses the "River of Beirut," by a conduit twenty feet wide built of cut stone on three tiers of arches, still standing, the canal is one hundred and sixty feet above the bed of the stream. At this elevation it meets abrupt cliffs through which it passes by a tunnel cutting, to proceed on arches again, across the plain of Beirut. Remains of an aqueduct, probably still more ancient, cut through the rock under the existing city have also been discovered.

Considering the desolation which the country has continuously experienced during the last thirteen hundred years, it is a most interesting fact that Beirut to-day, is again supplied with water from the interior, and that this is done according to the modern system of hydraulics. To the American visitor who notices for the first time, in the pavement, the iron plates with the Roman capital letters, B.W.W., it seems strange that these initials should answer as well for "Beirut Water Works," as for those of Boston. The natural source for this modern supply is found in the *Nahr el Kelb*, or the *Dog River*, which with the ancients bore a name of similar signification, *The Lycus*, often mentioned in the local history. It is but a very short distance from the place where it empties itself into the Mediterranean to a narrow pass, between the rather inconsiderable stream of water and beetling cliffs which for thousands of years has been known as a highway of great commercial and military importance The limestone walls still display the sculptures and inscriptions here carved on them by successive nations in their day of strength and pride. Egyptian, Assyrian, Persian, Greek, Roman, Moslem and Crusader, have each in turn left here their memorial tablet. At various heights in the rocky flanks of the gorge are vast caverns, more or less accessible, ascending or descending in a labyrinth of chamber, some hung with huge stalactites, some traversed by streams descending in water falls to natural reservoirs ultimately communicating with the river. Others are accessible by boat from the stream at their entrances, and out of one of these issues

the principal feeder of the river; the ultimate source of all being Mount Sunnin, the tops of which are often seen from the city, covered with snow. Among the curiosities of the neighborhood is a natural bridge over the stream, which is now used as part of a traveled road, with a breadth of one hundred feet, the arch being at a height of two hundred feet and a span of one hundred and fifty. This undoubtedly is a relic of some more ancient tunneling wrought by primæval streamlets.

The water for the city is taken at a height of seventy-four feet above the sea by a conduit partly built up in masonry and in part tunneled through rock, which carries it to the pumping station, a distance of nearly three miles. Here the water is passed through filtering tanks, and then by turbine wheels worked under a fall of sixty feet of water, is subjected to a force sufficient to carry it to the city, a distance of about eight miles. The iron pipe, through which it is sent has a diameter, at the pumps, of twenty-four inches, which is reduced, gradually to eighteen when near the reservoirs over the town. These, two in number, are respectively at the levels of three hundred and twenty-five and two hundred and twenty-one feet above the sea. From these it is distributed immediately by pipes for ordinary uses. The supply is estimated to be quite enough for the domestic consumption of a population nearly double that of Beirut. But it is probable, in view of the tastes and habits of the inhabitants of the East, that a large proportion will be required for ornamental fountains. The water reached the town in the early part of March last, and in June there were already hundreds of houses supplied with it. The Porte had made it a condition in the franchise that one-third of the capital should be offered to the people of Beirut, but there was but one native of the town who subscribed—a gentleman who is now the local director, a man participating in the more enterprising spirit of western countries. The people in general, probably, saw little difference between such an investment and one in their national loans; in which they never, at least not voluntarily, take a creditor's position. English capital for the most part has supplied the means. The work has been conducted throughout to its completion by a British engineer, Mr. W. J. Maxwell, of Belfast. Natives, under European gang masters, were employed; except for the tunneling and machinery. The main tunnel is nearly eleven hundred yards in length, in which distance four shafts, the deepest being two hundred and thirty feet from the top of the rock, were sunk for the construction, allowing the horizontal piercing to proceed from ten faces at once. On this part of the construction, Italian as well as native laborers were employed, working night and day, and it was opened through in fourteen months. Mr. Maxwell, on the completion of the work, has returned to England. M. Briffeux, a very courteous French gentleman, is the superintendent at Dog River.

Beirut is even now an exceptional city in the East. It has various flourishing industries of silk, wool, cotton, iron and jewelry; with constant and increasing direct communication with Europe and America. The old narrow streets have in some quarters been widened. There are European hotels, pleasantly situated and well kept. There may be found a highly cultivated society from among the families of the merchants of various European countries, the clergy of various creeds, and the ladies and gentlemen connected with the missions for evangelization and schooling, whose headquarters for Syria are in the city. Reliable physicians, educated in Europe or at the medical college in Beirut itself, are at hand. For invalids seeking more complete change of scene, with a mild and healthful residence among agreeable surroundings, the place presents many attractions. Damascus is reached by diligence over a Macadamized road, recently made by a French Company, and for those able to travel on horseback with a tent equipage, there are excursions to the Cedars of Lebanon, Baalbec, and on to the Holy Land, for which Beirut is a good starting point.

If the Euphrates Valley Railroad should be constructed, Beirut will probably become its terminus on the sea. When the British Government, in 1840, saw fit to maintain the sovereignty of the Porte over Syria, against the Egyptian dominion, the city was bombarded from

an English fleet. It seemed probable that the contrary policy will now be pursued, and that Egypt will be the ally in any of the struggles that may ensue. Whose *protection* it shall be that will be extended over Syria and Palestine may be more questionable.

The traveler in those countries even now feels that it is England, or more properly, the British empire of commerce that is "in the air;" far more than any other European influence. Perhaps the battle-cry "God for" Victoria, "England and St. George" may be soon shouted in the very plain close by Beirut and around the chapel, now a Moslem shrine, dedicated to his memory, where the warrior Christian had his celebrated tussle with the dragon monster.

AIR BAGS FOR RAISING VESSELS.

From "Engineering."

Air being seven hundred times lighter than water, a bag made of a very light water-tight material, when filled with air affords easy and powerful means wherewith to raise sunken bodies. Air bags are convenient for stowage and transport, because when not in use they occupy very little space, while at the same time when wanted they can be expanded into large dimensions. The greater the weight of the body to be lifted by means of air bags, the larger of course must be their displacement, and as the bags are generally manufactured of certain fixed dimensions, the weight of the submerged body must determine the number of air bags to be applied.

The first to suggest the use of air bags for this purpose was Professor St. Claire, of the University of Edinburgh, who proposed them in the year 1785. But as the india-rubber industry was then but barely developed, air bags could not then have been manufactured of that material so as to be of practical use. So recently as in 1864, air bags were for the first time practically applied by Bauer for raising the steamer Louis, which sank in the Lake of Boden. But on that occasion, owing to the bags being pear-shaped, they could not sustain the pressure and gave way. The idea of using the air bags in Russia originated with M. J. Alexandrovsky, and the system was adopted in 1865 at the time when the turret ironclad Smertch foundered in the Baltic Sea. Mr. Alexandrovsky was supported by Admiral Popoff, of the Russian Imperial Navy, who assisted him greatly in bringing his invention into practice, carrying out experiments so as to render the air bag system what it now is, namely, a very valuable means of raising ships, &c., and which has already rendered good service to the Government and commerce of Russia on several occasions.

The air bags adopted in the Russian navy when inflated are of cylindrical form, measuring 12 ft. in diameter, and 20 ft. in length. The useful part of their displacement or their lifting power in practice averages 60 tons. Air bags measuring 15 ft. in diameter and 20 ft. long will lift about 100 tons, and cost, according to the number required, from £375 to £350 each in St. Petersburg. The skin of the bags, of the sizes mentioned, is composed of three layers of the thickest canvas, saturated with india-rubber. Between each of the canvas layers is a sheet of india-rubber. The two inner layers of canvas are made up of strips sewn together along their edges, and laid in the direction of the length of the bag, whilst the third or external layer is made of canvas strips surrounding the bag circumferentially. The strips of this last layer thus cross those of the layers underneath it. This arrangement of the skin layers secures in the bags the required amount of resistance and durability. The external surface of the bag is fitted with special straps through which it is surrounded with a close, strong rope net, which increases the strength of the skin, and a layer of matting is interposed between the skin and the rope net.

In order to distribute over the whole surface of the bag the strain to which it is subjected when lifting heavy bodies, the bag is enveloped in a series of longitudinal and transverse, or circular hempen cables. To the lower ones iron eyes are fastened, which afford means to connect the chains securing the bag to the object to be raised. When necessary an oak beam 12 ft. long and 14 in. or 16 in. square is attached to the cables which surround the bag transversely; and to this beam the connecting chains are made fast. Each of the air bags is fitted with a valve, which is screwed in at the top and in the centre, together with an india-rubber hose, by means of which air is forced into the bag. At the ends of the bag, also in its upper part, are two smaller valves with tubes intended for letting the air out, and for holding the pressure gauge, which is applied for the purpose of ascertaining the amount of pressure inside.

In the interior of the bag, along its bottom, two short lengths of hose are sewn in so that they cannot move laterally. One end of each of these pipes which is open terminates close to the end of the bag and in the interior of it, whilst the other end passes out at the opposite end of the bag at the bottom, and is fitted with a safety valve, which opens when the bag is fully inflated with air and the pressure begins to exceed the surrounding water pressure. By means of these two safety pipes and valve the bag is secured from bursting, and the pressure of the air within it distributes itself evenly in both ends of the bag. The bottom part is fitted with a man-hole sufficiently large to admit the entrance of a man for inspecting the interior of the bag and for repairs.

In order to lift the sunken vessel, it is necessary first to send down divers to examine her condition, and to find the spot where it would be most convenient to pass chains or cables underneath her keel. For this last purpose the divers at first pass a thin rope underneath the bottom of the vessel, which is followed by a rope of greater thickness, attached to the first and terminating at the other end by a chain or the cable. It sometimes happens that the power of the divers below, and that of the windlasses above, though sufficient to draw a thin rope under the vessel are insufficient to haul a thick cable. In such cases an air bag is attached to the end of the thin rope, and this bag being inflated acquires an ascending power sufficient to carry with it a cable of any required thickness. This method was successfully adopted, when a vessel sunk in a depth of 15 fathoms was being raised, and when the power of 200 men with windlasses proved to be insufficient to draw the chain underneath the vessel.

When several chains have been drawn underneath the bottom of the ship the air bags are attached to the ends of each of them, as near to the bottom of the ship as possible. The bags being inflated by means of air pumps cause the ship to rise. Before pumping air into the bags, care is taken to connect together all the chains which surround the hull of the vessel in a transverse direction, so as to form a longitudinal continuous belt, which uniting all the chains into one system, prevent the end pairs of air bags sliding off from beneath the extremities of the vessel. As the ship rises the surrounding water pressure decreases and the excess of air passes out from the bags through the safety valves, with which each air bag is provided.

This method of raising vessels and other sunken bodies by means of air bags is of very great importance, especially when the work has to be performed in the open sea, because in rough weather the bags without any air in them can be left under water with buoys to mark their position, until the weather becomes more favorable and the sea calm.

When lifting vessels from great depths, the work must not be accomplished by one process, that is, the whole number of air bags required to complete the work should not be applied to the ship at one time. This precaution is necessary, because, when the vessel, tied up with chains and provided with the full number of air bags, ascends rapidly from a great depth and gets to the surface of the water, it is raised, by means of its acquired momentum, higher than is consistent with equilibrium at the surface. Eventually after attaining an unbalanced position, the whole is submerged again. This arises from the circumstance that from the moment the

ship leaves the bottom of the sea and during her ascent the surrounding water pressure is gradually decreasing and the air from the bags is passing out. Therefore, at the time when the ship reached the surface of the water, the bags would not possess the amount of lifting power necessary to keep her on the surface. Accordingly the ship would return to the bottom. To prevent this one, two, three, and in some cases four bags (according to the size of the vessel), out of the whole number required are fastened to the chains, which surround the vessel, not close to her, but at a depth of some two or three fathoms below the surface of the water. By such distribution of lifting power, the vessel, having separated herself from the bottom of the sea, would ascend until the upper bags reached the surface of the water. The whole system is then towed to another place, where the water is shallower than where the wreck occurred. The air bags which reached the surface of the water at the first operation are again submerged and are tied to the chains several fathoms lower down. By repeating these operations several times, according to circumstances, the ship will be brought to the surface gradually and by easy stages with the certainty of success.

These precautions are also necessary in those cases when, as it sometimes happens, the sunken ship, after having separated herself from the bottom of the sea, would be raised not horizontally, but with one end higher than the other. By having several air bags, out of the whole number, attached at a depth of a few fathoms below the surface, it insures that the rise of the higher end of the vessel will be limited only to the height equal to those few fathoms, and the chains with the air bags surrounding the ship cannot slide from underneath her. This method of working affords a sure means of ascertaining whether there is any necessity to increase or decrease the lifting power at either extremity of the vessel.

In the year 1869 a merchant schooner foundered in the Baltic, and in order to save her heavy cargo, consisting of pig iron, air bags were made use of. This case proved how powerful the air bags were, because, when the upper part of the vessel was surrounded by the longitudinal belt of chains with the air bags attached to it, her deck, with the whole of the masts, spars, and fittings, together with the upper strakes of her sides, were torn away by the power exerted by the bags, and were carried up to the surface, the breakage occurring just along the line where the bags were applied. After having thus opened the hold her cargo, and afterwards the vessel herself, were lifted up easily and successfully. The next useful work performed with the air bags was the lifting in 1870 of the gunboat Metch, which sank in the roads of Tranzund in a depth of 21 ft.

Soon after this in the same year the steamer Ilmen, which had foundered near Viborg, was raised. The work was completed in the short space of ten days, thus proving the simplicity and ease with which the air bag system can be applied.

In the same year the ironclad Sevastopol was lifted for repairs by means of bags, so that access was obtained to the wooden planking separating the armor from the copper sheathing. The edges were calked and the planks replaced by new ones. By these means in five days only, and with very little expense, the leakage from which the frigate suffered in 1869-70, and also the destruction of the lower armor plates due to the action of copper sheathing, were successfully stopped. Had not the bags been employed, it would have been necessary to place the frigate in dock, and as the docks at Kronstadt, at that time, were not so deep as they are now, this work would have necessitated the removal of her armor—a heavy and very costly job or the frigate could not have been commissioned until the new dock was completed. During the same year also, air bags were used for raising the stern of the ironclad frigate Minin. With the help of two barges and four air bags, the frigate was successfully conveyed over the Neva bar to Kronstadt. In 1870 the imperial yacht Standart being raised by means of eight air bags was conveyed in a similar manner over the Neva bar. In this work also the use of air bags greatly reduced the expense and saved much time. In the same year the air bags were utilized for lifting up the stern of the ironclad Prince Pojarsky,

when she was brought through the gate of Petrovsky Kronstadt Dock, where the ship had her armor plates put on and whence she could not be taken out without taking these plates off again.

In 1872 in Biorke-Zund, a vessel sank in 90 ft. of water. It was intended to lift her by means of barges, but this attempt failed, after much time and money had been spent. On the attempt being made with air bags, the work was successfully accomplished, notwithstanding that this vessel, owing to her cylindrical form, her comparatively small size, and her very heavy weight, proved to be very difficult to raise. The lifting of this vessel thus from the bottom of the sea showed that the work could only have been successfully carried out by means of air bags.

The system afforded no less important aid in 1873 in the Black Sea, where the necessity occurred for changing the pitch of the propelling screws of the Popoffka Novgorod. The form of this ship did not allow her to be taken upon any slipways existing at that time. This work required but three bags, and by means of them the stern was lifted to a height of 5 ft.

Last year a merchant steamer, the Dornkat, which foundered in 11 fathoms of water near London Lights, in the Baltic, was lifted by means of 8 air bags. Notwithstanding that at the beginning of the work the steamer was surrounded on all sides by the ground at the bottom of the sea and was buried in it, and that the work was carried out in an open sea, the steamer was successfully raised.

In the autumn of last year, by means of the air bags, the stern of the Popoffka Novgorod was lifted twice for the purpose of lengthening the blades of the propelling screws and to change their pitch. This year air bags have been usefully applied on several occasions, and at present they render great services in the construction of the new bridge across the Neva in St. Petersburg. In this case they are used to keep in a vertical position the iron caissons during their erection. It will thus be seen that the air bag system is in every respect one which may be of great value to the royal and mercantile navy.

THE LATEST NEWS ABOUT RAILWAYS.

From "The Builder."

So much attention has recently been directed, in various quarters, and with various objects, to the actual condition of railways, that our readers may be glad to have a few words on that important subject. Absolute novelty, indeed, can hardly be expected to characterize our remarks. But even novelty is not absent; while information as to what is more important, steady progress, either occurs or is demanded at every turn.

So accustomed have we become to the greatest mechanical triumph of the nineteenth century, that we almost cease to note how absolute is now our dependence on this method of internal transit. In the good old times, when one, two or even as many as four-and-twenty four-horse coaches ran, in the course of the four-and-twenty hours, past some famous roadside inn, an allowance of a horse per mile was considered adequate to the requirements of the very first style of travelling. When the coaches were full each horse would have to draw four persons; and if the same team ran twice in a day over an eight mile stage each horse would draw four persons for sixteen miles, or one person for sixty-four miles. We are not in possession of the actual number of horses thus engaged, but we may call to mind one fact which no longer exists, and that is the great disproportion in the amount of travelling for business purposes which was wont to distinguish the winter from the summer season, arising from difficulties during the latter that now no longer arise.

At the end of 1873, there were existing, on the 16,082 miles of railway open

in the United Kingdom, 11,435 locomotive engines, which were used for the traction of 362,785 vehicles of different descriptions. Thus, the locomotives amount to 71 per mile, and the gross total of vehicles to 22.56 per mile. But carriages used for the conveyance of passengers only are only 24,634, or a little more than 1½ per mile of railway. There is no distinction given between the passenger and the goods engines; but as the vehicles not used for conveying passengers which are attached to passenger trains amount to 9,128, we have a general plant for the passenger and light parcel circulation of 33,762 vehicles; against cattle, merchandise, and other general wagons, amounting to 329,023, making the dead traffic provision very nearly tenfold that for the live human transport. We may thus conclude that something like 1,200 will be the proportion of exclusively passenger locomotives.

Whatever may be the exact distribution of the engines, this running stock of 33,762 vehicles provides for a circulation amounting to 455,320,188 passenger journeys; besides the uncounted journeys of 314,579 season-ticket holders. The gross weight of minerals and general merchandise conveyed is returned at 190,953,457 tons. If we allow four journeys a week for every season-ticket holder, and two hundredweight for each passenger and his personal luggage, we shall find the passenger tonnage amounts to rather less than 50,000,000 tons, or about one-fourth of the merchandise weight. The total receipts from passenger trains amounted, in 1873, to the sum of £23,853,892; that from goods and minerals to £31,821,529. Thus the passenger income is 43 per cent., the goods income 57 per cent., of the total. The expense of wear and tear and interest on capital sunk in construction of the vehicles destined for the two services is difficult to ascertain. But against the higher cost of the passenger vehicles may be set the greater speed at which they run, and the very much shorter period of time for which they are idle. Taking these elements into account, it is probable that there is not a very material difference between the earning power of equal sums invested in passenger and in goods vehicles. At this rough approximation something like 20 per cent. of the annual expenditure will be incurred in carrying on the passenger traffic, which earns 43 per cent. of the gross receipts; while the remaining 80 per cent. of expenditure, incurred by the goods traffic, only earns 57 per cent. of the gross receipts.

We do not, of course, state these proportions as absolutely precise. We give the figures on which they were based, which are those of Captain Tyler's report for the year 1873. They appear to us to be approximately correct. Our readers have the opportunity of checking them. They point to very important results. The gross total railway income of 1873 was £55,675,421, of which £30,060,112 were expended in working and maintenance, and £25,615,309 remained as profit, allowing an average dividend of 4.64 per cent, on the total capital of £588,320,308.

In other words, the average earnings of every train came to 67.71d. per mile; the cost per train mile being 36.57d.; and the net earning 31.14d. per mile. The total train mileage is 197,354,749 miles. Thus 54 per cent. of the gross returns are expended in earning them. Whether from the natural difficulty of the case, or from any other motive, those statements which might enable us to ascertain the relative net earnings of the goods and passenger traffic are absent from Captain Tyler's report. It is for this reason that we have entered into the analysis of one element of that distribution of cost,—the carrying power allotted to the two great descriptions of traffic. With a special machinery of nine-tenths of the whole provision for traffic, the carriage of three-fourths of the gross weight transported over the lines has earned only 57 per cent. of the gross revenue. According to this rough approximation, the portion of the income arising from goods, viz., £31,821,529, is earned at a cost of 75 per cent. of the gross charge, or of £22,545,084; while the passenger receipts of £23,853,892 have been earned at the cost of only 25 per cent. of the gross charge, or £7,515,028. That is to say, that the net earnings of the goods traffic have been only £8,967,637, or about 28 per cent. of the goods expenditure, while the net earnings of the passenger traffic have

amounted to £16,338,864, or about 217 per cent.,—more than double the expenditure,—for the passenger traffic.

Rough as this approximation is, it is by no means certain that the disproportion would be reduced by greater exactitude. As it stands, it is clear that, even if it cannot be said that the goods traffic of our railways is carried on at a positive loss, it is carried on at a great relative loss, as compared with the passenger traffic. It results that a line constructed for the exclusive conveyance of passengers, supposing it to have full employment (which would be the case with many of our most important lines if they were thus restricted), would earn four times as much for the shareholders as a goods line, in proportion to the running expenses. When we come to divide the net profits over the capital, it seems to be pretty clear that a goods line alone would involve an annual loss, as its net train earnings would not pay 1½ per cent. on the capital. A passenger line alone would pay upwards of 15 per cent. on the capital. Therefore our actual dividends are kept down to below 5 per cent. by the goods traffic.

This consideration is one that eminently deserves the attention of railway proprietors. Any miscalculation we shall rejoice to have pointed out. It is pretty certain that the managers of many of the lines can, if they think fit, tell the actual differences in the profit of their passenger and of ther goods traffic. The practical part of the case lies here. Most of our lines are so choked with traffic that the construction of some mode of relief is only a question of time. Throughout the country exists a very elaborate system of water-carriage, which it has been the policy of the railway companies to discourage to the utmost, although in many cases the canal property is in their own hands. Are we, then, in order to leave the rails free for passenger traffic, to construct new lines for the heavy traffic alone, which will pay only 1½ per cent. on the new capital, or are we to endeavor to relieve the present glut by recourse to the cheap, though slow, method of water-carriage?

Full statistical returns generally enable an analytical observer to extract information which may not, on the face of these returns, be at first apparent. It is, however, remarkable that the report of Capt. Tyler is blank as to every particular that would enable us definitively to compare the relative profit of the goods and passenger traffic. The subject is one which must have so often engaged the attention of all competent railway managers, that the absence of such information is remarkable. It can hardly be accidental. We may be in error, but it certainly seems to us as if the returns had been purposely so constructed as to withdraw from the control of the shareholders any useful information on this subject. In our early returns as to the railway expenditure the outlay on land, works, and rolling-stock was always separately stated, as were also the legal and Parliamentary expenses. In the present return, all this has disappeared. We have elaborate statements of capital, how varied, and what are the dividends that it bears; but the very important matter of the objects to which the capital has been devoted is passed over in silence. We are thus unable to ascertain, even approximately, the cost of the different portions of this working-stock, of which the numeric items are given. This is a serious defect, and detracts much from the value of a report which ought to be exhaustive. The bearing of this silence on the point under discussion will soon become apparent.

If we consider that the locomotive stock enumerated has cost £1,500 per engine, which is probably a good deal under the mark, and that the carriage, wagon, and other rolling stock has averaged £150 per vehicle, we shall find that some seventy millions, out of a gross capital of 588 millions, have been laid out in working stock. We are under the impression that the figure is below the mark, but let it be taken as a guess. The plant required for the passenger traffic is, as we have seen, numerically only about a tenth of that required for the goods traffic. But as the more expensive carriages are to be found in this division of the working stock, let us assume that each passenger vehicle costs three times as much as each goods vehicle, and that the passenger plant thus stands to the goods plant, as to cost, as two to five. This would leave fifty millions as the cost of

the goods plant; and we shall be very glad to have the actual amount substituted for this rough guess. We cannot estimate the annual interest and deterioration of this plant at less than ten per cent. If we consider, then, that the railways were all made at a certain cost, irrespective of the traffic which they were intended to convey, we should have an annual sum of five millions to charge against the goods traffic, after running charges had been defrayed, before absolutely net earnings would accrue. But we have already seen that the earnings of this traffic, deducting working charges from receipts, on the principle of proportioning cost to weight carried, amount to only some nine millions sterling. This sum is now reduced, we see, to four millions sterling. As to the enormous outlay on the construction of stations, cranes, warehouses, &c., for goods alone, and the annual charges, carried to the general account, which are due to goods traffic, we have no means of forming an estimate. There can be little doubt that they would swallow the greater part of the remaining four millions. At any rate, it is extremely unsatisfactory that, whether we analyze the annual expenditure, or the distribution of capital, we find in each case that the information which would enable us to speak with certitude as to the relative advantages obtained by the railway companies from passengers and from goods traffic is, in each part of the returns, carefully kept out of sight. It is not an unnatural supposition that this has been done in order to prevent comparisons that must seriously affect the question of the true policy of our railway management. Sooner or later the economical law of working will become known. It will be better for the shareholders if it is sooner rather than later.

The policy of railway management, while it is a subject of national importance, may be said primarily to concern the directors and shareholders of railways. It is otherwise with the safety of railways. As to this every one of us is directly concerned. There have been more than usually numerous indications, of late, that the public attention is somewhat anxiously fixed on this subject. It was the only one on which the President of the British Association thought it necessary to bring forward new matter, thrown into tabular form, in his opening speech. It was discussed, with admirable temper and scientific precision, by Mr. Bramwell, in the mechanical section. It is the subject which has called forth an extraordinary proposal from Sir David Salomons, which he has brought before the world in a pamphlet, having first secured such profits as may flow from a patent. And the Board of Trade returns for the quarter ending June 30, 1875, which are just published, show that the loss of life daily incurred on our 16,000 miles of railways forms an appreciable item in the death-rate.

Sir John Hawkshaw has shown, by the sure method of statistical comparison, that the risk of injury faced by a railway traveller is, as matter of mathematical expectation, very trifling. Only one passenger has been killed, from causes beyond his own control, out of 13,165,000 passenger journeys, between 1846 and 1873. Only one passenger, under the same limitation, has been injured out of 4,045,000 journeys. And in the decade ending 1873 the deaths inflicted on passengers, in proportion to miles travelled, were reduced to two-thirds of the ratio that obtained in the preceding decade.

The daily press retorts on this statement with what some people call a common-sense view. "Don't tell us," says the public commentator *de omnibus rebus*, "about relative safety and proportionate accidents. Give us facts. You kill so many persons. Why is that? Somebody ought to be hanged, and the ouly question is who."

No persons are so loud and obstreperous in their demand for facts as those who are utterly unable to make any rational use of them. The real meaning of the demand generally is "I will not listen to argument. I don't care for your explanation; an accident is an accident, and you cannot talk it away." In actual truth, however, facts are generally of little or no use to the general auditor or reader, until they are collected, sorted, and collated by some one who has a due knowledge of their significance; and that is exactly what Sir John Hawkshaw has done in the present case.

There is, however, one point of view which we may consider as novel, if it were only from the fact that neither Captain Tyler, in his report for 1873; Sir John Hawkshaw, or Mr. Bramwell, in their papers at Bristol; Sir David Salomons, in his pamphlet on signalling; nor any other authority recently before the public, has supplied the information requisite for the statistical analysis which would enable us to investigate it as fully as we could wish. The railway service of this country is, in point of fact, a service of extreme danger, from mechanical causes. It is carried on at a considerable cost to human life. It is true that familiarity with danger, leading often to carelessness, may be detected, in most cases, to be the proximate cause of disaster. But however this human weakness may come into play (as it does, happily, in all circumstances of danger, or life would be far more full of apprehension than it is), it is the rapid motion of great masses of matter in the immediate vicinity of crowds of human beings that is the prime cause of danger. And this is a cause inseparable from the rapidity and ease of our travelling.

The actual number of the persons employed by the different railway companies is not given in either of the papers to which we have referred. Sir John Hawkshaw says, in round numbers, that it amounts to a quarter of a million. The total number of casualties on railways for the quarter ending June 30, 1875, was 1,431, of which 261 were deaths. Of the casualties, 933, 157 of which were deaths, occurred to servants of the companies. This gives a death-rate of 2.5 *per mile*, and an injury rate of nearly 15 *per mile per annum*. If we compare this with the colliery death-rate and injury rate for the year 1869 (when we brought that subject before our readers), we shall find a considerable difference in favor of railway safety. 1,116 lives were lost in that year by 854 separate colliery accidents; the total number of male persons employed in collieries being 345,446, of whom 282,473 were miners. It will be observed that deaths alone are given in the one case, deaths and injuries in the other. One live was lost out of every 309 persons employed in the coal mines, being at the rate of 3.23 *per mile*; or one-third more, proportionately, than in the railway service. In the latter it seems that there are about six injuries to one fatal injury.

We may look at this comparison in another light. The 1,116 lives lost in coal mining in 1869 were destroyed in the course of operations that resulted in the winning of 108,003,482 tons of coal; being at the rate of one life lost for every 96,777 tons of coal won. We have seen that the tonnage moved by our railways in 1873 may be roughly taken at a paying load, in goods and passengers of 240,000,000 tons. If we take the death rate of the last quarter as characteristic of the year we shall find the proportion to be only at the rate of one life for every 400,000 tons of load moved. The safety here is more than four-fold, in proportion to the work done. The danger arising from velocity is, to this extent, better watched against than the dangers arising from the peculiar circumstances in which the miner works.

A further measure of the natural danger attendant on rapid steam travelling may be taken from the fact that during the last quarter twenty-one passengers were killed, and 132 were injured "from their own misconduct or want of caution." This part of the return, which has no analogy to any other with which we can compare it, as a special value. We see that the system is in itself so dangerous as to cause 15 accidents in three months from the inadvertence of the sufferers. In the working of this system, moreover, a certain sacrifice of the staff occurs, which, although of a magnitude not to be slighted, is far less than that which occurs in the provision of one supply of fuel. And yet we find that only two passengers have been killed, and 182 injured in the same quarter, from causes beyond their own control. The number of passengers during the quarter is not stated; but from the data given for 1873, we estimate that it must have been considerably over 120,000,000. That only 184 injuries, two only of which were fatal, should occur in a circulation of 120,000,000 passengers, certainly denotes a very high degree of safety. A man cannot ride, drive, boat, or even walk the streets

of a crowded city, with so little risk of accidents, as he incurs when travelling in a railway carriage. To some extent his comfort and safety are insured by the risk of the servants of the company; but even as to this, his supply of coal has paid a heavier life-tax than his provision for travel has involved.

Small as this personal risk is, it may be stated, with little hesitation, that it is not the fault of the civil engineer that it is not altogether extinguished. Mr. Bramwell has shown how analyses of the causes of casualties have led, in almost every instance, to the provisions of safe-guards that would be perfectly adequate if faithfully applied. The cause of railway casualty, in the present state of science, is almost exclusively economical. It is the neglect or disuse of precaution, whether in order to avoid expense or to avoid fatigue, that is almost invariably the cause of disaster. Over-working of railway servants,—which means undue provision for the requirements of traffic,—lies at the bottom of most of the trouble; the natural imperfection of the human machine, when not over-worked, accounts for a comparatively trifling remainder. From this cause, we fear, there will always arise a certain element of danger, though an element that may be reduced to a very low value.

It seems tolerably certain that the engineering science of the day has arrived at the best distribution of precautionary measures under these three heads, viz., —mechanical appliances, telegraphic communication, and human watchfulnes. All three are needed. It is almost invariably the last element in which failure occurs. It is, therefore, by an attention to the moral and physical condition of the railway servant that the sources of danger are to be, as far as possible, eliminated. For this reason ingenious inventors, who, like Sir David Salomons, are endeavoring to throw the duty of human watchfulness on mechanical automatic contrivances, are working in the wrong direction. It is not necessary to analyze Sir David's proposal of a complicated addition to the block system. Its adoption would add nothing to the advantage of that excellent system, but would substitute a mechanical method of indication very likely to get out of order, and therefore most treacherous in its action, for a plan which only requires inflexible enforcement to insure safety. And it would make this change for the worse at such an outlay,—upwards of a million and three-quarters,—as prevents the need of further discussion. It is a remarkable instance of the love borne by inventors to the off-spring of their own brain that reflections such as these should not have occurred in time to save Sir David the expense of printing his little book.

TOOLS.*

From "Iron."

THE word tool may be said, when taken in its broadest sense, to include every mechanical device that man has conceived and embodied in a material form in order to aid his own efforts in the accomplishment of his own purposes, more especially where the application of force is implied. They range from the first smooth stone used by the savage up to the self-acting mule or the Walter printing machine, including even the locomotive engine, or any other higher development; for through them all, from the smooth stone upwards, one idea passes into another so gradually and imperceptibly that it is now impossible to draw a distinct line at any definite point, the conventional classification or nomenclature which is now employed being merely a matter of convenience to enable us to distinguish one sort of tool or device from another. The great point to realise clearly at the outset is this, that all mechanism, of whatever nature or by whatever name it may be known amongst

* Abstract of an address by Dr. Anderson, delivered at the opening of the Exhibition of Appliances for the Economy of Labor at Manchester.

men, is in each individual case the result of the material embodiment of an idea, that the original idea was first conceived in the human mind, and then by the means available at the particular period of the world's history man has been enabled to reduce the mental idea into a material, tangible form. According to Carlyle, the first tool used by the prehistoric man was a smooth stone, selected for a practical purpose, to be employed against his foe, or to aid him in killing wild animals for his daily sustenance. In course of time the idea would gradually dawn upon the mind of some other man of an ingenious turn, that if a long leather thong was attached to a stone, with the other end of the thong having a loop to pass over the right wrist, he could thereby save the trouble of having to look for and find the stone after each effort, and he could sit quietly under the shade of a tree in waiting for the prey, and hurl the stone without having to change position for its recovery; the assumed thong would thus be the first decided contrivance for the saving of labor.

Of the earliest invention of tools, or the first applications of mechanical force to perform work, there is no existing record. Man's first effort with tools lies far beyond the reach of history or even tradition. The tool arts existed for thousands of years before Greece had reached the period of her artistic greatness; the tool art was ancient and mythical long before Romulus or Remus had been fondled; even far beyond the time when the Egyptian pyramids were erected for then tools were in a highly advanced stage, of which there is ample evidence. Those great works were not carried out by the apprentice hand of man. In searching for the origin of tools we have to go a long way still farther back—away up into the somewhat mythical region of our own old fatherland, the home of the Aryan race, somewhere in Asia, where there is evidence that tools were familiar long before the Aryan swarms of colonists set out to people Hindostan, Persia, Greece and Rome, and nearly the whole of Europe. It is interesting to read the account of the ethnological investigations that have thrown light upon the condition of tools during that period. We read that the words relating to tools, industry and peaceful pursuits, to the domestic animals, to the weaving of cloth and the working of metals, have the same roots in the languages of all those nations, but that the words relating to war and most other subjects were originated by the several branches after the Aryan family had been broken up, thus showing that tools, the arts of peace and industry, must have been long established, otherwise the names of tools could not have been so firmly rooted in the minds of the entire race, to be retained in the memories of the whole stock in their respective colonies, when they, one by one, found a resting-place in other lands, including even our own little island home. On reaching the times of Euclid and Archimedes we find tools highly advanced; the principles of tools are clearly understood, and about 130 years before the Christian era there is a pumping steam-engine at work in the courtyard of Hero of Alexandria, the pump having an air-vessel attached to produce a constant jet of water, similar to the modern fire-engine of John Vanderheyden. Both Pliny and Cicero refer to the tool called a lathe, but it is doubtful if they mean the lathe tool of our time; it is more than probable that they refer to the class of lathe which is now extensively employed in Birmingham for spinning sheets of metal into bowls or dish-covers, but in those early days the sheet of metal seems to have been laid on the table of a sort of potter's wheel, which would afford the same result.

In the automatic or self-acting tools of this generation the great distinguishing feature of the larger number is this, that when once the tools are in working order they do not depend upon the attendant for the result. This condition is obvious in the tools of the textile manufactures, and almost equally so in the class of tools that are employed for the treatment of metal, wood and stone. In the latter, when considered in a general way, there is a family likeness running through them all, not so much in their outward appearance as in their principles of action, and still more in their adaptation to trace out the required form or pattern from a permanent copy embodied in the tool by a process of transfer. In the intelligent examination of such mechanism the first thing to ob-

serve is the manner in which this leading feature has been developed, and it will be interesting to compare in each separate tool how the primary idea of copying the form has been embodied in the material structure, because this is the very point where a man shows his superiority for ingenuity, skill, craft, or taste. Although the ways in which the idea of copying is embodied are innumerable, still it will be found that in almost each case the means employed are exceedingly simple.

To select, for example, the familiar tool called a lathe; it is chiefly intended to impart to materials true circles, straight lines, and flat surfaces, and all of those conditions must first exist in the tool. The bearing surface of the spindle neck must in itself be absolutely round in the strictest sense, otherwise the article operated upon will not derive a true circle from the revolution of the spindle. The mathematically true circle here referred to is practically very difficult to attain. There are many tools in the world that are supposed to be round, but which are not so in reality. An examination of the Whitworth gauges will best convey the idea of what is meant by mechanical truth and a true circle, each part fitting accurately into the other, yet perfectly free in every position. Then again the lathe has to afford absolutely straight lines of movement for the guidance of the cutting instruments, whereby the true circle derived from the spindle and dead-centre point is developed into a true cylinder, but not so unless the parent circle and straight lines are correct in themselves. If a perfectly flat surface is required from the lathe the cutting instrument must pass in a straight line transversely to the axis of the revolving spindle, and if the two are set absolutely at right angles to each other a correctly flat surface is the result. If, however, any of the conditions of accuracy are wanting, then imperfection in the produce will follow as a matter of course. If the lathe is intended to afford screws it must first have a perfect screw within itself to copy from, for if there is any imperfection in the screw copy, or in the divisions of the teeth of the wheels by which it receives collateral motion, the screw produced will contain a transferred copy of each imperfection. It will thus be seen that the lathe is simply a tool to transfer its own character to other things; hence the paramount importance of having the lathe perfect in itself.

Unfortunately, the world, as a rule, does not sufficiently appreciate the difference between perfect tools and tools nearly perfect; but in the government of this portion of the world it is so arranged that those who do not are invariably punished because the want of truth and accuracy entails greater cost in their production, both at the present time and hereafter. To take another notable example—the well-known tool for planing metal—it is a sort of lathe, but differently arranged, and is intended chiefly for the transfer of flat surfaces; it is, however, frequently employed for the production of cylindrical surfaces, or even cones, both figures being obtained on the same principle as in a lathe, namely, by combining, although in a different manner, the straight lines of the machine with the circles of some appendage on the table. As in the lathe, so in the plane, if the latter is not absolutely correct in itself, in all its lines or transferring surfaces, its productions will be imperfect also, and much more costly, if they have to be rectified by hand tools afterwards. The family relationship that subsists between the lathe and the plane is very intimate; neither have much resemblance to their old ancestor, the Aryan potter's wheel, and still less does the lathe resemble its more immediate progenitor, the dead-centre lathe, worked by the alternate motion of a wooden lathe, which has given the family name to its many illustrious descendants.

Another member of the lathe family is the drilling machine. There are other tools of the same family, known by various names, in which the principal motion is given to the cutting instrument. They are variously arranged for movement in any required direction, vertically, horizontally, or otherwise; but the leading feature in all is the copy from which the transfer movement is effected. In another class of tools the required form is embodied in a circular cutting instrument, which is guided unerringly by an iron arm, when the revolving cutter shapes out the reverse of its own form,

as in cutting the teeth of wheels; but the circular cutter may be guided in any other course, regular or irregular, or the article may be simply passed under the cutter, and thereby rendered capable of developing any kind of figure which may by required in the whole range of the arts of construction. In all those tools, and in many others not mentioned, it is wholly a system of copying from a pattern by transfer, and the methods of applying the principle are practically unlimited.

The great lesson to be drawn from the consideration of this principle of transferring from a copy, where the tools merely repeat themselves, and thus become the parent of other tools of the same nature, is this, that the progeny of the said tools have the good or the bad qualities of the parent tool from which it was derived; that if the original tool has not truth inherent in its own structure, whether of true circles, straight lines, or the many other tool virtues, then the tool cannot impart those virtues to other tools, nor is it possible for any real goodness to come out of a bad automatic tool. Hence the importance of having the highest excellence in the innate qualities of the breed; and where it does not exist in the stock naturally then the virtues can only be acquired by reverting to the more primitive class of hand tools. By means of hand labor, combined with extreme care, skill, and patience, the sought-for conditions of truth are ultimately reached, and at a great expense; and the desiderated virtues once acquired and embodied in the automatic tool, will transfer themselves to other tools *ad infinitum*. After copying, the next important point to observe in machine tools is the instruments which men by experience have found the best adapted for treating different materials either by cutting or detrusion, and likewise to note the rate of motion at which the cutting or detruding operations are found to be most efficiently effected. The natural laws which determine the conditions here referred to are not clearly understood at the present time, but there is now an immense number of facts accumulated that point in a particular direction, but have not yet been generalized into laws.

One hundred years ago the cutting of cast iron was a secret which few men could practice. Cast iron appeared to be most obdurate in its resistance to the cutting instrument. From the circumstance that man's past experience had been acquired in the treatment of wood and the softer metals, which admit of high velocity, the earlier attempts to bore and turn cast iron on a large scale failed, because the force was applied in a wrong condition. As experience was gained, it became apparent that a much slower velocity, combined with greater pressure, was necessary, which entirely overcame the difficulty. On one occasion Mr. Bolton, in writing to his partner, James Watt, said, in effect, that the completion of the bore of a cylinder by a new boring bar was most satisfactory; the piston fitted so nicely throughout that there was scarcely room for the insertion of a half-crown at the worst part. In these days of Whitworth tools we can scarcely realise their practical difficulties, which were overcome one by one through the skill and indomitable perseverance of Wilkinson and Murdoch.

The range of velocity found most suitable for different substances lies rather wide; cast iron, for example, requires a slower motion than wrought iron, and may be said to range between 12 to 20 ft. per minute, according to hardness; sandstones, from their structure, require a slower motion in the planing machine when being shaped into blocks or columns; and a slower motion still is found necessary by the Aberdeen granite turner, where the action is detrusion and the edge of the detruding instrument or disc moves in unison with the granite column. Going in the other direction, the limit of speed has scarcely been reached; a velocity of 8500 revolutions per minute is employed in the fine cutting of wood, and even that high speed is not found to heat the instrument to a degree which would necessitate discontinuance of the operation. It is different when the piece of wood itself is driven at that speed, as in the case of woodturning, because from the friction exerted on one point only the temper would soon be taken out of the cutting instrument. The remarkable difference arises from the swift revolution of the cutting instrument, where two new conditions are found to step in. The first is that due

to the extent of the cutting points on the circumference of the instrument, where each point acts in turn, thus giving a momentary rest to all the other points. Then, secondly, from the instrument whirling at such a high velocity, it is in the position of a blowing fan, and is thereby kept cool by the presence of the atmosphere.

There are some other minor points in tools besides those already mentioned which are of great practical importance. When a good tool has been once completed, with all the cardinal virtues, then the question arises, Has it the conditions of surface both in regard to extent and hardness that will enable it to see a reasonable old age and yet retain its original faculties, both in regard to truth and accuracy? Now tools differ greatly in this respect. Some tools make a fair appearance at the outset, but a few years' hard usage seems to take all heart and character out of them, while the properly constructed, sound-surfaced tools retain their excellence for a long period. The materials for tools chiefly consist of cast iron, wrought iron and steel. So far as the toolmaker is concerned in fashioning them into form, the principle of copying by transfer is again the leading feature. A pattern is first made for the founder, which he imbeds in sand or other refractory material. When the pattern is removed the mould or empty space is filled up with the liquid metal, which runs into it by gravity. Beyond this it is almost entirely natural law which the founder has to study and obey in order to obtain good castings, and the founder's practice is chiefly derived from former experience of success or failure, which is just as true philosophy as that which is grounded upon the inductive theory of the thinker, and, as a rule, is equally reliable.

From a number of causes which were in operation during the previous 400 years, chiefly occurring in Italy, France, Germany and England, there begins the gradual dawning of a new era in tools; an entirely new race grew out of the old race, with this wonderful peculiarity and difference, that the idea of mental conception is not merely embodied in the material form, but, in addition, the man's own mental faculties are transmitted to and remain an integral part of the tool. By this change man relieves himself from the drudgery of having again and again to repeat himself. He is not only relieved from the physical toil of using the hammer or the distaff, or other tools, but he saves his mental labor as well. Thus the intellectual thinking of the brain becomes a part of the automatic machine. This second stage of tools embraces the larger portion of modern devices for the treatment of materials, including the mechanism of textile manufactures, and generally, but not necessarily, they derive their force through motors which are independent of man for their effect. It is useless to quote examples in Manchester because they are the leading and distinguishing features of the district for spinning, weaving and working of metals and wood. There is yet a third stage of a still higher order of capacity in tools. There are modern tools which not only have ideas embodied in them like the tools of the second order, but in addition they have what we may almost call a reasoning faculty; they have the capacity of putting several ideas together, then summing up the existing conditions, and arriving at a practical decision in a fraction of a second, a mental process which would occupy a learned philosopher for hours, even if furnished with all the facts of the case. Then there are other tools which are provided with a nervous system, which pervades their mechanism, whereby if any disorder of their normal condition occurs they instantly communicate the fact to a sort of brain and stop of their own accord. Other tools perform the most difficult mathematical calculations, and are capable of printing the result, so that no error may occur in the copying.

When we think of any sort of material beyond the working treatment of their mechanical properties we seem to be in another world. Take, for example, a piece of common wrought iron; it seems to us as of the earth earthy, but if we are closely questioned in regard to the reason for its various properties we find that we scarcely know anything. Tracing it from the ore through its various stages until it is in the hands of the smith is comparatively easy. We know the natural law that governs its elasticity, the limit of its elasticity, its ultimate

strength ; that it can be welded ; that it is ductile and can be drawn out into a fine wire ; that it is malleable and can be spread out into a sheet or work round from the sheet into a goblet, and may be gathered back again, if by so doing it served any useful purpose ; but when we think of the marvellous changes which have taken place amongst its molecules during the operation we are lost in wonderland. To many minds the piece of cold iron seems to be a solid ; under the pressure of the testing machine it is shown to be an unstable fluid. When the smith has the misfortune to leave a piece too long in the fire it vanishes ; it has found evil companions, and gone off under an assumed name and a new character. When a piece of iron is broken and carefully examined under a microscope we can see that it is composed of fine crystals ; but these crystals, we are told, are composed of innumerable molecules, which are not to be seen by the microscope, being smaller than the human mind can imagine; still, the smith feels himself under their influence. In homely words he speaks of the iron being "red-short" or "cold-short," without thinking that he is on the threshold of some of the impenetrable secrets of nature. The steel maker can take advantage of the molecular properties. With heat he can push them asunder and infuse amongst them the subtle vapor of carbon, and the iron becomes steel, highly improved in most of its mechanical properties, and with an increase of strength and elasticity. It may be inferred that each iron molecule is a little world in itself, surrounded with a thin wrapping of infinite space, no single molecule being in actual contact with any other molecule. We have reached the limit of sub-division so far as the engineer dare venture. The investigating philosopher, however, ventures much further with his speculations ; he tries vainly to penetrate into the supposed ultimate atoms of matter of which the molecules are composed, but further we need not follow. Suffice to say that a piece of common wrought iron is altogether a mystery, and teaches man the lesson of humility.

It is an interesting question to consider how the district of Manchester became so celebrated for its tools and machinery. Doubtless there were many causes of a material nature which contributed to the result, but the true cause of Lancashire superiority lies much deeper. As a youth in Manchester, fresh from Scotland, now thirty-six years ago, I was then strongly impressed with a certain marked mental peculiarity, and after spending the interval in a public department, where there was ample opportunity of studying all phases of the working mind of this country, it appears to me that the secret of Lancashire greatness in her own tool specialty is due to the deeply inductive turn of mind which there prevails, and that the inductive habit of mind is the central pivot around which all the other causes that have combined to make Lancashire what it is do revolve. No doubt some of the peculiarities are partly traceable to the line of the Teutonic branch through which they came, their early and inordinate liking for useful work, in combination with a natural inventive faculty, which has now continued for centuries, and grown deep into the nature of the population. Few have had more opportunity of observing the character of workmen than myself, and long since I came to the conclusion that the best practical workmen on the earth's surface are the men of Lancashire. They and their fathers, for more than four generations, have been under a course of training for this pre-eminence. This practical superiority is a consequence of the early introduction of the cotton manufacture among the people of Lancashire—a race who like work for the sake of working—and to the precision required in the making of cotton machinery.

The turn of mind of the genuine Lancashire workman is decidedly practical, and is rarely metaphysical like the Scotch or German. He seldom thinks deductively. His turn of mind leads him from facts to the advanced idea of an improvement, or up to the principle on which the idea is founded. The mind of Watt, for example, was the opposite ; he thought out by a deductive mental process, from speculative principles down to the material idea embodied. This habit of mind, notwithstanding all his marvelous inventive power, would never have made him distinguished in tools, nor

would it have enabled him to achieve the stupendous results that came through the inductive minds of Arkwright, Hargreaves, Crompton, and their successors. Watt arrived at the separate condenser by the reverse process that Arkwright arrived at his great invention. Both are typical of their respective modes of thought, deductive and inductive, from principles down to facts, and from facts up to principles. Watt's mind was full of Black's speculations on latent heat and the radical defects of the Newcomen engine, which he thought out deductively in various directions before the glimpse of a separate condenser came upon him like an inspiration ; even then it was vague and abstract, but, by continuous thinking, it took a concrete form that would afford the practical condenser. Even now the Scotch mind is deductive, and Scotch deduction has to be brayed for years in the English inductive mortar before it becomes great in the class of tools that depend on induction for their contrivance. At the same time Scotch deduction has paid back to England, with compound interest, all that she has received ; many of her sons have become your honored citizens ; and, as engineers, their names are household words wherever the English language is spoken. Even Adam Smith alone, by his deductions on the wealth of nations, has done enough for the trade of Lancashire to entitle him to a niche in the Manchester gallery of fame to the latest posterity. By the foregoing happy combination of circumstances, which acted and reacted on the Lancashire mind for a number of successive generations, Manchester became the cradle of machine tools, and the nursery-ground to grow the men who became the instruments for their development.

From the distinguished position that Manchester occupies as a great tool-making centre it will naturally be expected that everything displayed at the Exhibition here will be the very best of its kind in order to maintain its reputation before the world. The first exhibition of the same nature of which we have any definite account took place between two and three thousand years ago. The class of articles there exhibited consisted of "white, green and blue hangings, fastened with cords of fine linen and purple, to silver rings and pillars of marble; gold and silver bedsteads, with pavements of red, blue, white and black marble." We read that it was kept open for six months, and at the conclusion a grand banquet was given which lasted for seven days; to this feast were invited all the princes and nobles, as well as the people from one hundred and twenty-seven provinces. The wine was supplied from the royal palace, and all drank out of vessels of gold, each goblet being of a different pattern. The official report is contained in the first chapter of the Book of Esther. Although modern exhibitions may not contain such profusion of wealth and magnificence, nor commend themselves to the minds of the æsthetical by having each article of a different pattern, and, therefore, only at the command of the very wealthy, still they contain that which is immensely better, the tools whereby the necessaries and even the luxuries of life are put within the reach of the people generally, who, equally with the rich, can enjoy the comforts and elegancies of civilized life. Such things in a working man's home tend to refine the character, to increase self-respect, and to make this little earth a happier world to live in. Besides, your tools and machinery are not only wellsprings of civilization, but still more especially they mitigate the toil of countless millions of the human family. Considered in all their bearings, tools are a mystery; they help to dilute the poison in the sting of the primeval curse, and in some measure to restore to man a small portion of his original birthright.

We understand that the candidates for entry at the various royal dockyards as engineer students have not been very successful in the competitive examination by the Civil Service Commissioners. There were upwards of 100 candidates to fill the vacancies in the dockyards, and of these considerably more than half could not pass the examination. At Chatham Dockyard there were six vacancies to be filled, but it is announced that of the candidates who presented themselves for examination only five succeeded in passing.

—*The Engineer.*

DRY ROT IN TIMBER.*

From "The Building News."

Mr. T. A. Britton has done good service in bringing together into a portable volume all that has hitherto been collected and written respecting that most insidious foe of the builder, Dry Rot. Mr. Britton's experience and facilities have enabled him to avail himself of a fund of varied information relating to the subject. He tells us in his preface "he has availed himself of the assistance of professional friends, builders, timber merchants, foremen, and carpenters," and has been able to record instances of the progress and cure of dry rot. There has been certainly a great deal of mystery as to the origin and cure of dry rot, which Mr. Britton's treatise will help to dispel. The author has consulted also the professional journals of England, America, France, and Germany; and the works of Evelyn, Tredgold, Du Hamel, and other writers who have endeavored to throw light on this stealthy disease have been laid under contribution. The author does not profess to tell us of an unfailing specific that shall arrest and cure the disease, but he places all the known processes before his readers; he gives a fair hearing to every patentee, and adduces many useful instances of the application of simple remedies. Speaking of the origin of dry rot, he refers to a variety of authorities—Pasteur, Baron Liebig, Rondelet, Tredgold, McWilliam, William Chapman, &c. There is a marked difference, we need hardly say, between *wet* and *dry* rots. Wet rot exists only in damp situations. It generally proceeds from access of moisture from without, and may take place before the timber is felled. Dry rot, on the contrary, only attacks dead wood, and the causes which produce it are generally want of ventilation and contact with warmth and moisture. The fungi which attend dry rot, whatever may be their peculiar nature, result from, or are induced by, the conditions necessary for vegetable fermentation. Heat and moisture, no doubt, are the principle conditions required. Sap in a state of fermentation is liable to be attacked by dry rot under certain conditions. The fungus which thrives in this disease differs greatly in appearance, according to the body it lives on. In earth it is fibrous and white, and it may cause some alarm to be told that we might choose a site for our house which is vitally affected with the germs of the disease, and that, do whatever we may in the shape of precautionary measures, by ventilation under our floors, the evil is ineradicable, and that within a few years the house will become a prey to the disease. Such, however appears to be the case, and we know of certain localities in which the dry rot has appeared almost as soon as the buildings were finished. Mr. Britton relates a case. A London builder a few years ago, while building some houses at Hampstead, "found his men were never well; he afterwards ascertained that the ground was affected with rot, and that within one year after the house was erected the basement floor was in a state of premature decay." Sir Robert Smirke also noticed the liability of some situations to attacks of dry rot. Different fungi attack different wood; thus, oak in ships is attacked by a white membraneous fungus, *Polyporus hybrides*. The *Merulius lachrymans* called the dry rot, is one of the formidable enemies of timber. Dr. Greville thus describes it:—"Whole plant generally resupinate, soft, tender; at first very light, cottony, and white. When the veins appear, they are of a fine yellow, orange, or reddish, brown forming irregular folds, most frequently so arranged as to have the appearance of pores, but never like tubes, and distilling, when perfect, drops of water." Hence the term *lachrymans*, or weeping. This fungus is found in cellars and hollow trees. An excess of moisture appears to be inimical to the growth of fungus and dry rot, which rather requires a very moderate degree of dampness, or alternate states of moisture and

* "A Treatise on the Origin, Progress, Prevention, and Cure of Dry Rot in Timber." By Thomas Allen Britton, late Surveyor to the Metropolitan Board of Works, &c. London: E. and F. N. Spon, 48, Charing-cross.

warmth. Thus in very damp situations, the disease spreads far less rapidly than in dry ones, where the fungus becomes more fibrous, and the timber becomes covered with a brownish white membrane, soft and smooth, which often projects from the surface in white spongeous masses covered with profuse humidity. Certain spots are affected with fungiform protuberances. According to Mr. McWilliam "the fungi arising from oak are generally in clusters of from three to ten; those from fir timber are mostly in single plants, and these will succeed each other until the wood is quite exhausted." Wooden piles wholly immersed in water have been known to remain sound for over a thousand years, and an instance is recorded of a pile from a bridge on the Danube, which had been submerged 1,500 years. In posts, it is well known by the least experienced, that the rotting or decay takes place at the surface of the ground, or between "wind and water." Beams or joists generally decay first at the surface of the wall, or just within the wall. The ends of timbers are found liable to decay from the same cause. The fact is, wherever there is alternation of dryness and moisture inducing fermentation, the rot is induced, and timber exposed to these influences, or subject to moisture and heat, soon rots.

The use of inferior kinds of timber has contributed largely to the decay of ships and buildings. The firm old English oak (*Quercus robur*) is the least liable to the disease, while the *Quercus sessiliflora*, which is largely used in our dockyards, is sappy, and less dense, and not half so durable. Trenails, by not quite filling the holes, admit water and damp, and Mr. Britton says this is one cause of decay of wooden ships. Mr. Fincham, late principal builder in Chatham Dockyard, says dry rot cannot occur unless air, moisture, and heat are all present, and that the exclusion of any one of these stays the mischief. Ventilation, one of the chief remedies proposed by all authorities on dry rot, should be thorough. For example, the air should be dry to absorb the moisture and carry it off, so that the germs of the disease are not carried to other parts. In ventilating cellars and floors there should be a through current of air between the timbers, and not merely an opening, which would tend to accelerate and increase the growth of the fungus, as air has been known to do in some cases. In an article on this subject, we referred to the absurd practice of buying our timbers instead of allowing them free circulation of the air both at their ends and throughout their length; thus close-boarded and ceiled floors tend to rot the joists unless the air be admitted on two sides. The author wisely thinks, before admitting air to affected buildings and timbers as a remedy, it is necessary to ascertain its effects, and whether it will not tend to increase the disease. Warmth helps greatly to ferment the vegetable fluids when a certain amount of moisture is present. As to the temperature, Mr. McWilliam, in his work on "Dry Rot," says, at from 50° to 80° dry rot proceeds rapidly, at 90° its progress is slower, at 100° slower still, and at from 100° to 120° it is generally arrested. Many of our readers know the external signs of dry rot, but the following description may be useful to those who do not know the diagnosis:—"Dry rot first makes its appearance as a mildew, or a delicate white vegetation. The next step is a collecting together of the fibres of the vegetation into a more decided form, somewhat like hoar frost, after which it speedily assumes the leathery compact character of the fungus, forming into leaves, spreading rapidly in all directions, and over *all materials*, and frequently ascending the walls to a considerable height, the color variable—white, grayish white and violet, light or decided brown, &c." The italics are ours, as it cannot be too clearly borne in mind that dry rot attacks not timber only, as most people imagine, but brick walls and plastering, stonework, and, in fact, every material exposed to its ravages. We once inspected a brick wall of a dining-room (adjoining another house) which was completely covered with a thin tissue of ramifications like some kinds of fine fern. This appeared over the paper. We advised that the plastering be knocked off, and the wall replastered. Whether the fungus has since shown itself we cannot say. Of course the plant varies with the material from which it derives nu-

triment or support; in some timbers the fungi are more tenacious than others, and different stages of decomposition produce different appearances; some assume all kinds of shapes, from a stem-like growth to a velvety surface. We have before called attention to floor-cloths of an impervious kind as injurious to wooden floors, and we know cases where dry rot has appeared soon after kamptulicon or oil-cloth has beeen laid down. In floors that are either always moist or dry, or subject to alternate conditions, fungus is seldom noticed in the decomposition.

Noticing the use of timber, the author calls attention to the internal rotting often noticed in large beams of yellow fir, which have appeared sound outwardly. This is owing to the use of timber only superficially seasoned. Sawing and then bolting beams has been recommended for this reason; and Tredgold, we believe, first called attention to the desirability of this practice. The effect of dry rot is to cause the timber to shrink lengthways and break, and the part affected somewhat resembles charred wood; if a piece of timber in this state be pressed between the fingers it will crumble to a snuff-like powder. Mr. Britton enters minutely into this part of the subject, through which we cannot follow him. He proceeds to show how incipient rottenness is formed from the removal or sudden disruption of branches close to their roots; and some good lithographic illustrations of the modes of cutting deals, &c., accompany the letter press. Unfortunately dry rot may spread by the germs of the fungi to all parts of a building, besides those affected by actual contact.

Of the kinds of timber liable to dry rot some useful remarks are made—the length of time in the voyage, the condition of the ship's hold, its atmosphere, &c. Canadian yellow pine is more subject to the disease than Baltic or Canadian red timber. Turpentine is a preventive; hence the durability of red timber as a rule. Very few cargoes, we are told, arrive from Canada in which many logs of timber are free from vegetation, or the rot in its first stage. If the cargo has been shipped in a wet state, and the voyage has been long, a white fibre will be seen over all the logs, the yellow deal and Canada pine especially. These facts speak plainly to architects and engineers, and we question whether seventy-five per cent. of the timber used in average building is sound when used. The deals are packed flat-wise—no air can circulate round them, and the rot penetrates to a certain depth. Two other kinds of deals are very liable to dry rot—the yellow Petersburg and the Dram battens. White deal is more absorbent of moisture than yellow, and yellow more so than red; hence their more rapid decay in external situations. Some practical remarks on felling timber are given. For hard wood trees like oak and chestnut, sixty years is considered the lowest age, the average age being from 80 to 90 years. A tree of this age produces an average quantity of 75 cubic feet, or a load and a half. Chapter IV. treats of seasoning by natural methods, as hot and cold air, fresh and salt water, vapor, smoke, steam, boiling, charring, and scorching. Immersing timber in running water, and then exposing it to the wind, is a good method for sappy timber. Wheelwrights favor this mode of seasoning. Greater durability, however, is imparted by placing timber in a stream of lime-water 8 or 10 days; it becomes much harder and less exposed to the attacks of worms. This plan is best adopted after the timber is converted into scantlings, as there is then less labor involved.

For joinery, steaming and boiling are considered good methods, as the loss of elasticity and strength is compensated for by a less tendency to shrinkage. These processes are applicable to hard woods, as oak, which requires softening and bending for joinery purposes. An hour of time for every inch of thickness is reckoned as approximate. The author deprecates the use of salt water in seasoning planks by the process of boiling, as they are liable to effects of damp afterwards. Some contend that steaming prevents dry rot; but, as the anthor observes, low forms of vegetation are very tenacious of life, and it is very doubtful whether this process can destroy the vitality of the ferment spores. The bent planks on a ship's bows are shaped by steaming, and it is said that

this part is seldom or never affected with dry rot. We have therefore some evidence in its favor, and Tredgold says "boiled or steamed timber shrinks less and stands better than that naturally seasoned." Messrs. Davison and Symington's patent process of desiccation is spoken of as being of great value in seasoning floor boards and joinery. It consists in propelling currents of heated air *through* the wood, the heat being regulated according to the kind. The logs or deals are placed in closed chambers or flues of fire-brick, and the heated air, which passes through furnace pipes, is impelled by a fan through the chambers. The process does not char or injure the fibre, as stoving often does, and the vapor is removed as fast as it is expelled from the timber. Timber 9 in. square is the proper size to use. Mr. Bethell's patents are referred to, but the objection to them was that the heat required was too great, and tended to split the wood. A low temperature and long continuance of it are desirable in every desiccating process. Messrs. Holme, builders, of Liverpool, have used the warming apparatus of Messrs. Price & Manby with success, the heat and evaporation being gentle and even; the temperature employed is about 104°. The current of air through the metallic plates draws off the moisture from the timber most thoroughly.

The late Sir Charles Barry employed steaming for drying the wainscot, &c., of the Palace of Westminster—the best Crown Riga wainscot in the logs, and from pipe-staves being used. Smoke-drying is a very ancient mode of preparation. Dryden translates Virgil as follows:

> Of beech the plough-tail and the bending yoke,
> Or softer linden, hardened in the smoke.

The smoke destroys the fungus germ by its bitterness, and smoke from furze or shavings hardens the timber subjected to it. M. Guibert's method is to fill the drying-stove with smoke produced by the distillation of saw-dust, waste tan, smiths' coal, &c. A rotary motion is given to the smoke round the timber. Scorching of charring wood is unquestionably a good preventive of dry rot or decay so long as the inner portions of the timber have been thoroughly seasoned; or else it merely stops evaporation, and expedites decomposition within Mr. Vulliamy, a pupil of the late Sir Charles Barry, the architect of the Metropolitan Board of Works, to whom Mr. Britton dedicates this work, specifies for oak fencing, that the standards shall be filled in and rammed round with dry burnt earth, stones, and burnt clay, and that the "ends in ground are to be well charred before fixing." The charring of wooden posts is not new, being frequently adopted in the country; but the ramming with burnt earth, &c., is not so often seen as it should be. Charred piles last for ages, and the remains of burnt cities, as at Herculaneum, have revealed charred wood quite sound after 2,000 years. The charring of the embedded ends of beams and joists, and those used in warm and moist stables, is recommended. All butting-joints and junctions cut across the grain should be charred. Carbonization, by drying up the fermenting elements, and by arresting the putrefactive process, is at once one of the most valuable and economical means for treating timber we possess as an antidote to decay; and architects, who seldom think of these matters except when necessity compels them, should make it a rule in their specifications. Engineers have adopted the plan for railway sleepers from the first, and with good results. The author truly says that for oak and beech timber, which are hard to impregnate with mineral salts, it is particularly advantageous.

We are surprised the author does not appear favorable to Langton's method of seasoning by extracting the sap by causing a vacuum, or to Barlow's method for the same purpose. The former seems to us one of the most simple means, though it appears to have fallen through to make room for other more elaborate and costly processes.

We have not space left to say much on the careful summary of patent processes for seasoning timber. Our readers are tolerably acquainted with the preservative and seasoning processes introduced by Kyan, Bethell, Burnett and others, so we shall here simply allude to a few facts of value. The two last-named processes, Bethell and Burnett's, have been chiefly employed. Messrs. Bethell and Co. impregnated timber with

copper, zinc, corrosive sublimate, or creosote; and Dr. Boucherie's process for the injection of wood with the sulphate of copper, seems to have been successful in France, and promises well. Pyrolignite of iron is also used when it is desired to increase the hardness of wood; and chloride of calcium when the wood is desired to be rendered uninflammable and elastic. The process may be applied either when the tree is growing, or after felling; the preservative salts ascending the branches and impregnating every part. Dr. Boucherie's process aims at preventing not only rot, but increasing the hardness, flexibility and uninflammability of timber, and giving it various enduring colors and odors. We quote Mr. Britton's remarks at the end of the chapter:—"For the professional reader we have three hard facts: the most successful patents may be placed in three classes, and we give the key-note of their success. 1. *One material and one application.* Creosote, petroleum. *Order*—ancient Egyptians, or Bethell's, Burmese. 2. *Two materials and one application.* Chloride of zinc and water; sulphate of copper and water, corrosive sublimate and water. *Order*—Burnett, Boucherie, Kyan. 3. *Two materials and two applications.* Sulphate of iron and water; afterwards sulphate of lime and water. Payne." It is also remarked that the only three timber preserving works in London are owned by Messrs. Bethell and Co., Sir F. Burnett and Co., and Messrs. Burt, Boulton and Co.—all B's.

We endorse the opinion that we want a series of experiments on the application of chemicals to wood to resist "burning to pieces" without injuring it otherwise. It may be as well to remind our readers that the ancients were not ignorant of preservative processes. Garlic boiled in vinegar, tar, linseed, palm, and other fixed vegetable oils, especially when mixed with saline matter are preservative, and many of these were used.

One word as to our dwellings and the prevention of dry rot. As we have before remarked in these pages, builders will bed their bond and wall plates in mortar in damp walls, and use putrefactive ingredients instead of sand mortar. What can encourage dry rot so well? Cork or bark has been found to preserve greatly the ends of beams inserted into walls by plates of it wrapped round them. Hot pitch is a good thing to dip the ends of sills and joists into. Allusion is made to "damp courses." Taylor's perforated course, manufactured by the Broomhall Tile Company, is one of the best preventives we know of, as it ensures free ventilation at the same time that it arrests the rising of moisture. Yet our speculative builders heed not. They lay joists on damp brickwork, and stucco, and cover up the face of their walls as soon as possible to stop evaporation. What can be a surer way to dry rot? Sleepers and basement joists should be laid on cement concrete coated with asphalt—the latter material, we think, should completely line the basement of our houses like the copper sheathing of our floating vessels. Unfortunately the correct course in these matters is the one most shirked by the speculator. Thus, to tell him that his building should be left in carcase after it is covered in for some time; that after the plastering is done he should wait till it is thoroughly dry before the floors are laid; and that painting his woodwork must be avoided, would be to tell him to forego the most valued secrets of his trade. Paint, the great disguiser of imperfect workmanship and rotten, unseasoned materials, is, we are glad to see, strongly condemned; and wood of different kinds, shades and stains, recommended. Dark and hard woods could be employed for skirtings, stiles, &c., and lighter for the upper framing and moulded parts. Mr. Papworth has shown that paint is a comparatively modern introduction, and that it was not in general use till the time of William and Mary. Mr. Britton justly thinks house-painting was invented by a *bad* builder in the seventeenth century; and bad builders have been the prolific cause of dry rot and decay. Mr. Britton gives good advice in recommending all who speculate in bricks and mortar to employ an architect or surveyor; "it is the cheapest course." He categorizes seven classes of bad builders—1st, the ignorant builder; 2d, the bad builder, who has no money to carry on his business; 3d, the *partial* scamp; 4th, the *regular* scamp; 5th, the *thorough*

scamp; 6th, the "jerry" builder; and 7th, the *vagabond*. We have merely dipped into Mr. Britton's interesting volume, and we have left untouched the chapter on the ravages of the worms and ants. We may, perhaps, again have to notice it, but will simply give here in conclusion the general advice—"Prevention is better than cure"—"season and ventilate." When cure becomes necessary, the author's salutary advice is—Cut out and renew.

THE CORROSION OF BOILERS—ON THE CORROSION OF BOILERS WHEN WORKING IN CONNECTION WITH SURFACE CONDENSERS.*

From "Engineering."

In asking your attention to the subject indicated in the title of this paper, I may premise by stating, that what data I shall have the honor of laying before you, as to the corrosion of boiler plates when generating steam from distilled or redistilled water, will be generally such as has resulted from my personal observation. Much of it will doubtless be familiar enough to those whose professional experience has included the management of boilers whilst working in conjunction with surface condensers. In the earlier days of the practical application of these condensers (I refer to fifteen or sixteen years ago), you must be aware that engineers were often driven to their "wits' end" in striving to account for or to arrest the extraordinary and insidious decay which was steadily and rapidly consuming their boilers before their eyes, while yet there was no recognized means of preventing it. And, indeed, up to the present time, although we have by a primitive, and, withal, a makeshift expedient, been able in great measure to mitigate the evil, I am not aware that the light of scientific research has yet been brought to bear upon the subject with a view to determine the nature or cause of the action itself, or to devise any means of counteracting it.

Fully a decade of years has passed since the writer first endeavored to ventilate this question, by introducing it to the notice of gentlemen whose social and professional positions and interests warranted him in assuming that they would have influenced scientific inquiry in respect of the question. More recently I have tried to set forth the necessity for immediate and decisive action in the matter; but little or nothing of a practically effective nature has been done towards enabling us to grapple with or overcome the difficulty itself. At all events, for aught we have yet learned of the causes of the evil, boilers would decay as surely as they did on its first introduction. My reason for touching so intractable a subject, and pressing it on your notice, is the hope I have that you may add some ray of light towards elucidating the cause of boiler decay, or haply indicate some simple and economic means of arresting it. The subject is, as I think, well worthy of your best attention, since a deteriorating element like that under notice rests like an incumbus on the introduction of what otherwise is an invaluable adjunct to the efficiency of the steam engine.

About a year ago the Board of Admiralty, awaking to the factthat the boilers of the Royal Navy, working in connection with surface condensers, were becoming worn out before their time, and acknowledging the futility of trusting to experience alone to institute a remedy, appointed a "Commission of Inquiry" to take evidence and report on the management and condition of boilers generally throughout the navy. Especially the commissioners were instructed to ascertain the nature and cause of the operations which result in their premature decay, and to report thereupon. This "commission" was composed of one admiral, one captain, two shore engineers, and one chemist—all honorable men,

*Paper read before the Cleveland Iron Trade Foremen's Association, by Wm. Miller.

doubtless; and yet it is scarcely apparent as to what could be the utility of the fighting or navigating element in the commission. It ought to have included among its members at least two marine engineers having practical acquaintance with the management of boilers under steam at sea. These might have introduced or elicited important matters of detail such as would not readily occur to the minds of those who were strange to such duties. As it is, however, they will probably gather some useful information that may lead on to a good result eventually. Twelve months have passed since the labors of this commission commenced, and it was not too much to expect that some report—if only a preliminary one—might by this time have been published. Its appearance might have allured coworkers, equally capable, to their aid. Up to this time it is not visible, however, and we may wait in hope.

The process of surface condensation—by which we absorb the heat from the exhaust steam through bringing it into contact with cold metallic surfaces—although only generally recognized as a practical success within the past fifteen or sixteen years, is a process the original idea of which is to be traced back for a period of well-nigh two centuries. In the mechanical, as in the political or philosophical world, history frequently repeats itself, and seldom has it done so more distinctly than in the case of the surface condenser. So long ago as 1690, Dr. Papin, in one of his experiments made before the Royal Society, after generating steam in a cylinder until it lifted a loaded piston, removed the fire from under it, and allowed the steam to condense by the external temperature of the air, in order to produce the return stroke. About the same time Captain Savery employed the same process and cooled the exterior walls of his gathering vessels with water, in order to create a vacuum for pumping purposes. Contemporary with these we also know that Newcomen, in his earlier attempts to use steam as a motive agent, adopted a similar method to produce a vacuum in his cylinder, until he accidentally discovered that the water injected among the steam was much quicker in its action and better suited to his purpose. We can learn nothing further of the application of the process until the time of Watt, when we find him experimenting with both a "pipe" and a "plate" condenser, either cooled by an artificial air current or by submergence in a running stream, but both of which he ultimately abandoned as impracticable, giving preference to the common injection system. It was not until the year 1832, or about fifty years after Watt's successful adaptation of the "separate" jet condenser, that the true objects of the surface condenser came to be recognized as a desideratum in connection with the steam engine. In that year Mr. Samuel Hall introduced a condenser, consisting of a cast-iron chamber filled with copper tubes through which the steam exhausted, the water at the same time circulating round their outer surfaces. This arrangement met with considerable success, both in the royal and merchant navies. From all accounts it appears to have answered its purpose well; indeed, engineers who have had experience with it, have told the writer that it was all that could be desired. Yet for some reason which has not been sufficiently explained, the system fell into disuse until about 1858, when it was again revived. This time it gained steadily in favor with engineers, and within a year or two quite a host of patent arrangements were in the market. The principal difficulty with the earlier plans was in the making of tight joints between the water and steam chambers—joints that would allow for the expansion and contraction due to the varying temperatures of the tubes. This object has been accomplished by various methods, some employing cotton packing with screwed glands, others compressed wooden ferules, others sheet rubber with gland plates, and others with simple rubber rings of about ¼ inch section, without ferules, glands, or aught but their natural elasticity to keep them in place. I may remark that I consider this latter method to be the best—at once the simplest and cheapest—as, with considerable experience of the more elaborate arrangements I found it to give less trouble, and to be more easily rectified than any other.

The primary object sought after in the introduction of the surface condenser is to secure a supply of pure feed water for the boilers. Were this entirely practi-

cable, we should, after filling our boilers at starting, only require to make good what water we lost from leakage in the boilers, valves or connections, thus keeping the original water doing a continuous round of change—first water, then into steam, then again into water, and so on.

This pure feed supply would insure clean internal heating surfaces, with, of course, a corresponding economy in the fuel consumed; and in boiler cleaning the former, in the case of steamships, meaning a proportionately smaller bunker and greater cargo or paying space, in some instances no mean item in itself.

With the unquestionable benefits, however, which accompany the system, one very serious evil has arisen, and which considerably mars what otherwise would have been an almost perfect arrangement; this is, that a certain corrosive action has been found to attach to the internal iron surfaces of all boilers using their feed-water from these condensers; and so virulent in its character is this action, that what benefits we had expected to accrue from the use of distilled water cannot with impunity be obtained. It is therefore to a description of the nature and extent of this corrosion, with an examination of some of the more probable of the suggested causes and antidotes, that I now invite your attention.

A set of boilers, about four years old, supplying steam of 25 lb. pressure to a pair of engines indicating 900 horse power, and fitted with the common injection condenser, had been under my charge for several months, so that I had every opportunity of ascertaining their internal condition, which generally was as good and clean as could be had in boilers, working under ordinary conditions, with sea-water for feed supply. They had regularly "scaled" at intervals of from 14 to 18 days' steaming, and both tubes and plates were in very fair preservation.

Arriving in England, after having been 15½ days under steam, our old jet condenser was taken out and a new surface condenser fitted in its place. Believing that the distilled water we should in future use would remove what incrustation was on the heating surfaces, I did not go to the trouble or expense of having it removed by manual labor; but so soon as the alterations were completed, we had our boilers filled with fresh water and started on another voyage. On examining them after 12½ days steaming, we found that the saline deposit left on from the previous voyage had nearly all disappeared from the tube and plate surfaces, and was precipitated on the bottom of the boilers in good-sized flakes of scale. This showed that it had not been dissolved, but that the distilled water had insinuated itself between the scale and the skin of the iron, and so loosened its contact that the ebullition of the water repelled it from the surfaces. The internal surfaces were all as clean as possible, and apparently in perfect condition for the transmission of heat. The only signs of anything foreign to our ordinary experience was the presence of a grayish-colored and almost impalpable powder, which remained in contact with the plates above water-line; this, however, had no adhesive property, but was readily swept off with a hand-brush.

The color of the tubes and plates also was observed to be much darker than that due to the natural color of new iron; it was almost black, with a purple tinge about it, nearly resembling that of iron pyrites when denuded of its sulphur. A further examination, after having been another 15¾ days under steam—the while giving excellent results both as to steaming properties and economy in fuel—showed the inner surfaces to be quite clean, with the exception of a dark slimy deposit covering all the under-water surfaces. This, on the moisture evaporating, left as residue a dark brown pulverized substance of a fine sandy nature, but so thinly distributed that at the time we took no further notice of it. Over the water-line was the grayish-colored powder, similar to what we had previously seen, though in greater quantity than before, and specially thick in the vicinity of the uptake plates, but it came off quite as readily as before with a hand-brush, leaving a gray coating, but no incrustation, behind it. Although not again in charge of these boilers at sea, I had an opportunity of examining them after having been under steam during a further period of 33¼ days. The surfaces above and below water had been covered respectively with the gray and dark brown powdery deposit to which we have before referred, but, in addition,

the furnace crowns seemed to be eaten into by some corrosive action, not regularly nor thickly, but here and there, generally in rough blotches measuring from ⅛ in. to 1 in. across. We concluded at the time that the iron of which the boilers had been made was of an inferior quality, and that the pitted parts were patches of slag or cinder; further experience, however, led us to alter our opinion. Another case, and one which perhaps illustrates even more forcibly the rapid and insidious nature of this corrosive action, was one which was placed under my charge, on being transferred from that already referred to. In this instance both machinery and boilers were entirely new; the former were on the compound principle, and indicated over 1700 horse power, the latter were loaded to 65 lb. per inch.

At starting, our boilers were filled with fresh water, and only distilled water was used for extra feed supply, to recover our loss from leakage, &c.

On the seventh day out, on casually trying the salinometer in the water from the boilers, I found it to denote a density equal to about 2½ times the average density of sea-water; at the same time the water tasted quite fresh, though a little nauseous and greasy. The density steadily increased until the fifteenth day, when the hydrometer denoted a density equal to 17 oz. of saline ingredients to the gallon, or about 3½ times that of sea-water, the water at this time having a greasy-acrid taste, and very nauseous. On examining the boilers we found appearances much the same as previously described. Above water-line was the fine grayish powder clinging to the plates, and under water the dark brown slimy deposit, which, on the water drying up, left the same gritty powder, in color resembling, and which I concluded to be, an oxide of iron. The furnace crowns, and (as we afterwards found) the tubes also, were corroded, and this most erratically—one part of a plate would be quite thickly attacked, while another part of the same plate amounting in area to some square feet, would be left untouched; but generally the action had been most violent in the hotter regions, towards the junction of the furnace crowns and back tube plates. This "pitting" of the iron surfaces occurred sometimes in the smallest hollow specks, and again in large blotches over 1½ in. across, the depth varying from the merest impression to ⅛ in., the narrower indentations often turning out the deepest; indeed the tubes invariably gave way in little holes from ⅛ in. to ¼ in. in diameter. After the first voyage we filled the boilers at starting with sea-water, and ceased to use fresh water for surplus feed supply, but the decay still proceeded, though we thought less rapidly than before; and so it continued more or less steadily, until we began to change the water regularly, by blowing off a quantity from the bottom of the boilers, and replacing it by water from the sea, when the decay all but entirely ceased.

Such then is an outline, however imperfect, of the nature and progress of the corrosive action which attacts our boiler plates when working in connection with surface condensers, so far at least as this action has occurred under the immediate observation of the writer. These examples, however, by no means exhibit the extent of this action, as it occurred, in numerous instances; indeed, I know of one set of furnaces that were completely riddled through in their second year, and of a set of iron tubes which lasted only six months and a half, when they had to be taken out and the boilers retubed. Nor are these isolated or exceptional cases either, but the normal experience of all who have had to do with surface condensers in the earlier days of their introduction.

For this malific action there must, however, be some cause, could we but find it out. It is therefore with the object of leading your thoughts in the direction of the true cause that I now proceed briefly to examine some of those which have been suggested as conducing to results such as have been described. It has been with this, as with many other maladies, the nature of whose operations is hidden, or at least is not patent to the external senses, that there has been not a little diversity of opinion with regard to the agency at work in producing them.

Some of these suggested causes are indeed scarcely probable, and may justly be accepted as never having existed beyond the imagination of their originators; as, for instance, a chemical action

arising from the presence of chlorine or hydrochloric acid, said to be in the boilers, though, whence it comes, unless in certain peculiar circumstances, we have not yet been informed. When general attention first became arrested by this corrosive action, one cause suggested—and one which even yet obtains considerable credence—was the presence of an acid, said to be produced by the decomposition of the fatty lubricants passing from the cylinders into the boilers, and acting on the iron as a chemical solvent. No data of which I am aware, has yet ever been adduced in proof of the existence of any deleterious ingredients produced from this source; until, therefore, something other than mere assertion is brought forward to support the theory, I shall feel bound to dispute its correctness, believing, as I do, that all known facts tend to demonstrate quite the reverse. That this hypothesis has been ill-considered will at once be obvious when we recur to the old style of wagon-shaped marine boilers, generally contracted in steam-space, and consequently much given to priming, into which gallon after gallon of oil was injected to allay the turbid water, and this without ever a sign or sound of any ill effects resulting from its presence. While at all times it is the duty of those in charge of steam-engines to be frugal in the use of tallow in the cylinders, it becomes, when surface condensers are present, a very special duty to minimise the consumption of internal lubricants as much as possible, if only for the sake of the condenser tubes, which are readily fouled and very troublesome to clean. I therefore submit it is more than probable that much less grease will find its way to the boilers under the new than under the old style of condenser. However, with a view to obviate the injurious effects possibly arising from the use of certain, or of any lubricants, experiments were made with various kinds of oil, and in several instances the use of any internal lubricant whatever was entirely suspended; but these experiments, though invaluable in another way as showing the most suitable oil to use, went to prove nothing of the object for which they were undertaken. Under the writer's observation the decay still continued, where no lubricant whatever entered into contact with the steam, excepting, of course, what little could be carried by the rods through the stuffing boxes.

Another cause was suggested, and one which has of late grown largely into public favor. It is "the presence in the boilers of a galvanic action, induced by particles of brass or copper, which are loosened by attrition from the pipes, pumps, &c, and carried into the boilers by the feed-water." Now, as an exercise to the æsthetic faculties, we could conceive of conditions in which it might just be possible that such an action would be generated, and have the effect claimed for it. Granting that the water became acidulated through the presence of fatty acid held in solution, and granting also that particles of brass or copper could be precipitated over the internal surfaces, we should then have all the elements of an aetive galvanic battery at the points of contact with these metals, under whose subtle action the iron might slowly pass into solution as a magnetic oxyde.

I, however, would maintain that such favorable and (for the votaries of this theory I may add) favorite conditions do not exist. Firstly, because, this corrosion has occurred where no fatty or other acid could have been present in the water; even in the densest specimens of the redistilled water, acid was certainly not present to the taste. Secondly, the conditions were unfavorable to magnetic action, inasmuch as the corrosion occurred quite as frequently on the under as on the upper surfaces of the tubes and furnaces, where bodies of the specific gravity due to brass or copper were not likely to be deposited. Thirdly, in the next analysis of the under water deposit (scraped from the corroded parts) the percentage of foreign metals would not warrant us in assuming that these were present in such quantity as could possibly do any harm.

The analysis produced:

Oxyde of iron	77.5
Moisture	19.75
Grease	.85
Sulphate of lime	.8
Oxyde of copper	.6
Traces of alumina, chloride of sodium, and manganese	.5

With the object of diverting from the iron this assumed galvanic action, pieces

of zinc were hung in various parts of the boilers, in the belief that any acid present would, by its affinity for the softer metal, expend its energy on the zinc, and so leave the iron unaffected. I regret that I am not presently in a position to decidedly certify that this plan has made any difference either way with regard to the preservation of the iron, as at the time the zinc was first introduced we were already in possession of other means of arresting the corrosion. I, however, am not inclined to pin my faith upon its value, nor will it unduly establish your faith in the zinc remedy when I tell you that I never once knew its most ardent supporters to try it on its own merits, but invariably in conjunction with a plan which we already knew to be quite successful of itself; yet the zinc, suspended for a few weeks in a boiler evaporating steam from distilled water, will certainly decompose as well as could be wished, and will be taken out an amorphous mass, resembling the "clinker" from a firegrate, considerably increased in bulk, but possessing so little tenacity that it can be crushed between the fingers with no visible element of a metallic nature about it.

Another cause suggested, and the one which the writer believes, and has all along maintained to be the sole cause of this corrosive action, consists in the distilled or redistilled water itself, and in its use for feed supply. I was originally led to form this opinion from a consideration of the facts already laid before you. You will have noted that of the two sets of boilers to which I referred in describing the nature of this action, the decay in former showed itself after a longer interval, and did not proceed so rapidly as in the latter boilers.

While the former were under steam 61½ days before any corrosion was apparent, the latter had only been at work 15 days when they were observed to be more extensively "pitted" than the other. In looking round for some reason why there should be so marked a difference in the rate of progress of this corrosion in these different boilers, I concluded it was due to the cause specified, and for these reasons: first, because in the former boilers the surplus feed had always been taken from the sea, there being no provision on board for distilling it in sufficient quantity, whereas in the latter the deficit was always made up with distilled water only; again, the former bodies were frequently addicted to "priming." When this occurred (owing to the muddy nature of the water carried over into the engines) we shut off the feed pumps from the hot wall, and continued to discharge the water overboard until the boilers had ceased to "prime," these meanwhile being fed from the sea, and thus keeping the water in them more or less impregnated with a saline admixture; while the latter boilers, from their easy steaming properties, were not subject to this evil, the feed being at all times a uniform quantity, only regulated by the demand for steam. The conclusion naturally arrived at by induction from this data was that the extra supply of sea-water becam the saviour of the former boilers, whilst the latter wasted under the influence of the distilled water. The opinion thus formed I have yet had no cause to change; indeed all subsequent observation or imformation has, from my point of view, only tended to confirm it. Extraneous evidence, however, is not wanting in support of this theory (for such many will as yet only admit it to be), but our best hope for its early solution lies in the fact that it is surely growing into general favor. It is a well-known fact that all boilers fed with water from peat-bogs (which water is always nearly pure) do not last so long as those fed with ordinary water, containing a calcic or saline element in solution, while the decay occurs in the same peculiar manner as that induced through working in connection with surface condensers. As an instance of this, I know that some years ago it was a common practice for the locomotives running in the Sheffield district (on the London & North Western Railway), and using the water from the Yorkshire moors, to carry a quantity of carbonate of lime in their tanks, avowedly to neutralize the corrosive action of the pure water on their boiler plates. Another instance—as, I think, peculiarly confirmatory of the distilled water theory—occurred in a sugar refinery in Liverpool, in which four boilers were put down together; two of these sup-

plied steam for heating purposes, which, after circulating between the surfaces until it condensed, was again returned to the boilers as feed water. In this case the water, or steam, was conducted through nothing but cast-iron pipes (so that the galvanic action theory was untenable here), yet, after four year's wear, these two boilers were considered quite unsafe, and required to be extensively repaired, while the other two boilers, supplying steam for the machinery, and regularly fed with the town water, were, after the same term of service, scarcely a whit the worse. In the case of steam-warming apparatus also I have been informed that both boilers and pipes rapidly wear out, and doubtless this will be due to a similar cause. It is a well-established fact that distilled water has a most pernicious action on various metals, especially on lead and iron. Dr. Clark attributes this action to its peculiar property, as compared with ordinary water, of dissolving free carbonic acid.

The chemist Berthier also found that the nodular protuberances commonly seen in cast-iron pipes, when used for conveying distilled water, were composed of these elements:

Analysis of Nodules produced by Distilled Water on Cast Iron.

	per cent.
Protoxyde of iron	21
Peroxyde of iron	58
Carbonic acid	5
Moisture	14.25
Silica	1.33

In view, then, of the corrosive properties evidently possessed by distilled water, I would ask, might it not just be possible that the constituent elements of water, when frequently redistilled, undergo such a change as to greatly intensify its action on, or affinity for, iron? That some change does occur is plainly demonstrated by its very marked and steady increase in density. It is, therefore, with regard to the nature of this change that we so much want information.

A writer in a recent number of *Engineering*, whilst referring to the decay of boilers in the Royal Navy, suggests a course of experiments which must commend itself to all who may have the requisite education and opportunity to conduct them; this is to ascertain what part the influence of heat and pressure plays in modifying the solubility of bodies, with, of course, special reference to iron.

Under the hypothesis that redistilled water is the active agent at work in producing this corrosive action, various methods of neutralizing its effects have been suggested.

One authority suggests the introduction into the boilers of a quantity of silicate of soda or potash; another recommends carbonate of lime; another a mixture of the carbonate and sulphate of lime; while another proposes that the feed-water should be aerated. I am not, however, aware that any of these methods ever advanced much beyond the experimental stage, and some of them—the first and the last—I have never heard of even reaching this length.

The method generally adopted in practice is that of changing the feed-water. In experiments conducted for the purpose of ascertaining the amount of extra feed-water required I found that by blowing out a quantity equal to about one-ninth (.117) of that evaporated, and supplying its place with sea-water, I could generally keep a thin scale over the internal surfaces, though occasionally it would only be whitewashed. This changing of the water, however, requires to be done regularly at short intervals, and not hysterically (I found once every four hours to do very well), since, while it is an easy matter to fix a scale, it requires some little care to keep it and keep it thin. Such a scale is easily taken off without "chipping," if not allowed to accumulate in layers, but the tube ends next the combustion chamber—as the part on which the scale most readily gathers—must be carefully kept clean, especially when making steam of high temperature; for, with quite a little incrustation at this part, I have known the contraction caused by the injudicous opening of a tube door to make the whole "back end" of that box leak so badly as to necessitate the shutting off of that boiler, until the tube ends had been subjected to the expander.

Such, then, is the method—I might almost say the only method as yet adopted, successfully to prevent this malific

action. At its best, we must admit it is but a clumsy and a makeshift expedient, only to be tolerated until some better method of protecting our boilers is discovered. It is attended with many obvious disadvantages, not the least of these being that it places in the hands of careless attendants the power of doing serious injury to the boilers, besides interfering with their efficient and economical working. But, apart from all this, such a plan is only avoiding the matter, and is in no way leading us towards any better understanding of the nature of the operations which result in this corrosion, and until we have some definite knowledge of this, we can scarcely expect to devise any remedy that will strike at the root of the evil.

Yet, viewing in the abstract the question at issue, its solution will not appear to be beset with any insurmountable or even very special difficulty, were it made the earnest study of an experienced analytical chemist. The wonder rather is why it has not long ago received the attention it evidently deserved.

A comparison of the constitutents of such water as we know to be suitable for steam boilers with the constitutents of distilled water, and again with those of redistilled water of different densities, would not only greatly enlarge our knowledge of the nature and cause of the peculiar change which I have shown to take place in water during frequent redistillation, but it would probably acquaint us with the nature of such elements as, introduced into the feed-water, might counteract the evil complained of. Of course some difficulty might arise in the practical application of any elaborate chemical process, unless rendered automatic; but this, as an after consideration, may safely be trusted to the professional acumen of those specially interested in the matter.

One other matter—one strictly correlative to the subject under notice—which invites, I might almost say demands, our attention, is the necessity for the introduction into general use (wherever distilled or other similarly destructive waters are used in boilers) of a hydrometer, or other simple test for quality, one specially suited to the altered conditions of redistilled water, and noting the point, if any, up to which such water can be used innocuously.

Having in the outset of this paper given you my reasons for intruding a rather intractable subject on your time and attention, I trust you will accept those as sufficient, in some measure, to extenuate its choice. I have attempted briefly to trace the history of the surface condenser, from the embryo of two centuries ago, through its various progressive graduations, to the perfect machine of to-day—viewing it as the apparatus in conjunction with which the corrosive action of which we have been speaking was first brought prominently under the observation of all who had to do with them at work. In following sentences I have endeavored to describe the nature and extent of this action, noting by the way such of these incidental appearances and occurrences as are foreign to our normal experience with boilers, when working in connection with the old-fashioned jet condenser, or with high pressure engines, using no condenser whatever.

I have also essayed to point out some of the more probable of the theories which have been formed with regard to the cause of this action, laying before you, as these occur, my personal reasons for assenting to or dissenting from them, and I have presumed further to point out the direction in which I consider their natural solution to be found.

Yet, however positive may be the faith of individuals with regard to the truth or falsity of either of these theories, that they exist in plurality sufficiently proves that in its present state the question cannot generally be accepted as having emerged beyond the region of hypothesis; we still want the weight of acknowledged authority to finally determine the matter from experiment. Towards this end I invite your co-operation in the quest; I heartily court a full and free discussion of the question on its merits, and I earnestly commend it to the after-consideration and investigation of all who may have opportunity, confident that the complete elucidation of the cause and remedy for this corrosive action will be the certain reward of persevering effort, when we shall have placed within our reach all those benefits which we know must accrue from the use of pure feed-water in our boilers.

THE BAIE VERTE CANAL AND HYDRAULIC HERESIES.

By CLEMENS HERSCHEL, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

I RELUCTANTLY answer the article by Thos. Guerin, C. E., in the January number of this Magazine. Articles and counter-articles of this sort usually consist in the main, of foggy disquisitions upon points of misunderstanding; that the writer did all that in him lay to avoid every misunderstanding, in the first instance, may be gathered from the fact, that long before he thought of writing the paper published in the Transactions of the American Society of Civil Engineers, vol. III., p. 185, he wrote Mr. Guerin a friendly note, intended to draw out a correspondence upon a subject, upon which that gentleman had desired and especially called for comment and criticism. But, inasmuch as the extent of the change of base accomplished by Mr. Guerin between about September, 1874, and January, 1875, is equal to the differential expression of his path, integrated between the limits of Montreal, Canada, and San Francisco, California, it is not to be wondered at that this note was returned to the writer endorsed "Not found" by the P. O. authorities. Circumstances mentioned in the paper then gradually led to its production.

This answer to Mr. Guerin's answer is proposed to be tolerably brief; misunderstandings will right themselves; the profession or the public generally can little care for any personal element that may have been put designedly or inadvertently into the discussion, and the engineers of future tidal canals may safely be trusted to choose for themselves between the articles hitherto mentioned—trusted to reject the conclusions of either or both. To aid them somewhat in this task, it may be proper to point out, however, that having been brought up and trained in a school that incontinently condemns the hashing together in one formula of feet per hour, feet per second, inches per mile, 2240 pound tons per yard (and what not else), but rather elects to have uniformly only a few and simple units of measure (and I trust to live to see the day when even simple feet and pounds shall give way to still simpler metres and kilogrammes), having, as said, been in the habit of expecting only one kind of units, in one and the same formula, I may be pardoned for having overlooked the fact that in the formula $v=n\sqrt[3]{r}$ there was included a rise in feet per hour, a velocity in feet per second and a widely varying coefficient, not a constant. This is mentioned chiefly to explain how the values of n given in my paper were arrived at, all the velocities there, whether vertical or horizontal, being feet per second. How the table on page 56 of this vol. of this Magazine is found is still not clear. For example, if $v=n\sqrt[3]{r}$ certainly when $v=76.10$ ft. per minute $=1.302$ ft. per second, and $r=1.612$ ft. per hour, then

$$n=\frac{v}{\sqrt[3]{r}}=\frac{1.302}{1.173}=1.109,$$ instead of 0.550 as given, and similarly:

For $v=38.56$ ft. per minute$=0.643$ ft. per second, and $r=0.945$ ft. per hour, it would seem that n should equal 0.655, instead of 1.327 as given, all of which may be noted by future investigators. I take it, there will be no harm done, to quote in this connection, "He should have shown us how he got those figures." But, let Mr. Guerin or the future investigators seriously consider, what shall the profession do with a formula whose main-stay coefficient bobs about, according to Mr. Guerin, from 0.550 to 1.3313, and according to me (as far as I at this time think it worth while to pursue it) from 0.655 to 1.3313?

I desire further to call particular attention to the difference between considering the action of the first flood of water that is allowed to enter and run up on the dry bed of the proposed canal —an event that may happen one, two or three times in a year—and between considering the semi-diurnal action of the tide, in replenishing the amount of water used for locking during the two periods

of 12 hours each of every day, except the above one, two or three, that the canal is in operation. The first seems to have been Mr. Guerin's principal problem and starting point; and if so, then any conclusions drawn from such a mode of consideration, cannot evidently be applied to the action of a canal or estuary that does not run dry at low water. I submit, also, for the consideration of the profession, whether the action of the tide in running up a dry bed of a canal or estuary, and, owing to the "deferlement" or breaking up of the head and succeeding waves, presenting, as it does, the spectacle of a "bore,"—whether the details of such a violent, irregular movement, do not, for the present at least, go beyond the powers of mechanical investigation and formulæ.

The second view of the action of the proposed canal, is one that I have endeavored to investigate, and after careful study of the original books and articles of every one of the authorities quoted in the paper presented to the American Society of Civil Engineers, after experience of my own in constructing works of the class proposed, and after making special experiments to meet the case in hand—in some details an entirely new one, so far as I know—the paper just mentioned was written. It is suggested to Mr. Guerin and to the future investigator, that had he (Mr. Guerin) studied some of the works whose absence he deplores, more especially, perhaps, the works of D'Arcy and Bazin, it is reasonable to presume that his views would have received material modification upon many points. Take, for example, the statement on page 59 of this Magazine, this vol., that "no man of the ability of M. Bazin would state such foolish doctrine." In reply to that it will only be necessary to refer to page 55 and elsewhere of M. Bazin's work, where this doctrine is clearly demonstrated; but then M. Bazin considers the height of the wave itself, and much more of which Mr. Guerin (and he will allow me to say it) evidently has not the faintest conception, never having made a study apparently, of the latest experiments upon waves and wave motion.

Such elements of confusion, as assuming that the present writer is not aware of the distinction and difference between the velocity of the current and, what this same party has termed "the velocity of the beginning of the rise of the water," when the careful wording of this last term, no less than some emphatic remarks about the middle of the 5th page of his paper show quite the contrary; then going to work and battering down this man of straw, thus set up; further, pointing out approximations in formulæ explicitly given as approximate by the name of "errors;" and making merry because these approximate formulæ, though shown by experiments to be reasonably accurate when used between the limits of actual practice, do not, forsooth, apply to the extreme and bootless case of water rushing up the dry bed of a canal; these and similar obstacles in the way of the unwary seeker after truth, need scarcely a pointing out to the careful investigator.

The results of experiments and study, that I submitted to the profession in my paper printed in the Transactions of the American Society of Civil Engineers, as applicable to cases like that of the Baie Verte Canal, are still commended to them for their calm consideration.

In his report, just issued, Major Bolton, the Water Examiner, points out that the contamination of water from the gases generated by sewage is of more frequent occurrence than is generally understood. The gases are extremely liable to flow back into the cisterns and become absorbed by the water, unless the overflow pipe is brought outside the house and the end left exposed to the air, instead of being carried into the drain. The adoption of this plan will effect an object of great importance by getting rid of the poisonous effluvia and gases from the drains which would otherwise ascend through the pipe, and not only be partly absorbed by the water in the cistern but be partly mixed with the air in the houses, thereby becoming a cause of fever and disease. The attention of all householders ought to be given to their cisterns, which should be frequently cleaned out, more especially after periods of flood and turbidity, and every care should be taken to prevent the contamination of the domestic water supply.

ON THE RESISTANCE OF CYLINDERS AND SPHERES—FORMULÆ APPLICABLE TO THE CALCULATION OF HYDRAULIC PRESSES, FOR TUBBING SHAFTS, DAMS, &c.

By V. DWELSHAUVERS-DERY.

From the "Universal Review of Mining."

In his theory of elasticity, Lamé has arrived at exact formulæ relating to the thickness to be given to cylinders and spheres, subjected to regular pressure, in a direction normal to the surface, and uniformly distributed. These formulæ are only applicable to the case in which the strong pressure is on the interior, and the weak on the exterior. They are not adapted to the case in which the strong pressure is on the exterior, and the weak on the interior. Such is, however, the question which arises in the calculation of the thickness to give to tubbing and dams, and one which we consider important to solve.

The method by which Lame arrived at his formulæ is unassailable; he does not rely upon any hypothesis, and consequently, the correctness of these formulæ may be generally admitted. But this method is so dry, and the digressions are so long, that it seems to us hardly possible that these formulæ, notwithstanding all their exactitude, can ever come into general practice among engineers. England has had the good fortune to see Rankine solve these questions in a much more simple manner, in his work entitled, "A Manual of Applied Mechanics." But Rankine also stops short of the case in which the great pressure is in the interior; and, in addition to this, his formulæ are not demonstrated by direct reasoning, applicable to the subject alone, but they are rather deduced from more general questions, with which it is necessary to become acquainted beforehand. In my work, entitled, *Principes de la Résistance des Matériaux* ("Principles of the Resistance of Materials"), I have directly demonstrated the formulæ of M. Lamé, by a simple and ingenious method which Captain Devos had shown me for cylinders; but I also limited myself to the case in which the great pressure was in the interior. When consulted as to the thickness to give a spherical dam supporting a column of water of 150,000 kilogrammes per square metre (213,690 *lb. per square inch*), I was obliged to supply the omission which existed in my *Principes, &c.*, and got out a formula which was exceedingly simple and easy of application, one which deserved, in fact, to be inserted in all engineers' hand-books, in the place of those that are now found there, and which are, it may be said, sometimes misleading.

In applying to great thicknesses the hypothesis that the tension of matter under pressure is uniformly distributed, a serious mistake is made, and one which might prove fatal, especially in the case of dams or tubbing subjected to very great external pressure. One runs a risk, too, in hazarding other hypotheses, however rational they may appear, like those of Brix, for instance. It is evidently better to leave out of the question hypotheses as to the manner in which the tension is distributed, and rather seek to discover, by rational processes, the mode in which this really takes place. By acting thus, we shall be convinced that the co-efficient of resistance, which until now we thought the proper one to be employed, especially in the case of spherical dams, is much lower than the actual tension, as we shall shortly explain.

We will inquire successively into the four questions relating: 1st, to cylinders subjected to great internal pressure; 2nd, to cylinders subjected to great external pressure; 3rd, to spheres subject to great internal pressure; 4th, to pheres subject to great external pressure.

1st. *Cylinder. Great internal pressure.*—Let figs. 1 and 2 represent a hollow cylinder, closed by two ends of indefinite solidity, enclosing a gas which is capable of exercising a pressure of P kilogrammes per square metre upon all the points of the interior surface, and immersed in a gas exerting, in the contrary direction, and normally to the circumference, a pressure of P′ kilogrammes per square metre. We will suppose $P > P'$.

In its primitive state, the metal of the cylindrical covering is subjected to neither tension nor compression. The effect of the pressure, P, is to increase the internal radius, R, of the annular section (fig. 2), and thus to produce a

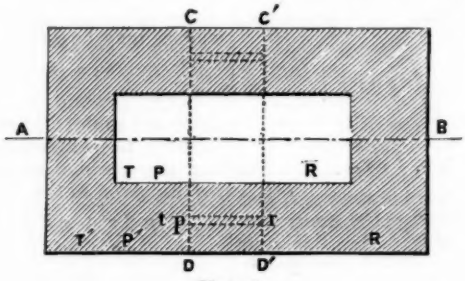


FIG. 1.

tangential tension on the circular fibres, a tension which varies from one fibre to the other, according to the radius, r, of the circular fibre. The pressures, P′, diminish this effect. But these same pressures, normal to the circumference, and in a contrary direction, exercise a second effect, which consists in diminishing the thickness $d\,r$, of the circular fibres, and consequently also, the thickness, R′ — R. The result is that each one of the circular fibres experiences a certain tangential, or longitudinal tension, which we will call t, for the fibre of any radius, r, varying from R to R′; T for the fibre of the internal radius, R; T′ for that of the external radius, R′. These fibres also experience a transverse compression (at right angles to the preceding) which we will call P, for the fibre of radius, R′; P′ for the external fibre of radius R′, and p, generally, for the fibre of any radius, r.

These tensions are all expressed in kilogrammes per square metre; the dimensions in metres; and we will consider the portion of cylinder comprised between the planes, C D, and C′ D′ (fig. 1), to be a metre in length. Under the different influences which we have just mentioned, the cylinder has a tendency to burst asunder in the direction of the plane A B, shown on the first two figures, and comprising the two sections, each a metre long, shown at A A′ and B B′, in fig. 2.

We will now proceed to solve the following question: *Under the conditions which we have just mentioned, what is the longitudinal tension* t, *at any point whatever of the sections* A A′ *and* B B′? *and what is the transverse compression,* p, *at the same point?* We will avail ourselves of this well known property: *when the circumference of a circle of radius,* r *is subject to a normal pressure, regularly distributed, of* p *kilogrammes per unit run, the force of these pressures, taken at right angles to any direction whatever, is* p × 2 r; *that is to say, that it is the same as if the pressure,* p, *exerted itself at right angles to the diameter only.* It follows that this force may be considered as distributed in two equal portions at the extremities of the same diameter.

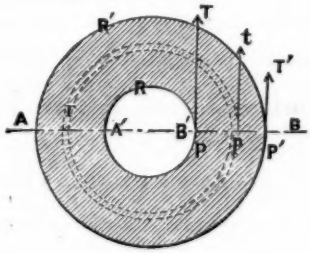


FIG. 2.

This granted, if we consider the fibres comprised between the radii, R and r, the resultant of the longitudinal tensions to which they are subject is equal to

$$\text{P R} - p\,r.$$

But inasmuch as t represents their longitudinal tension per square metre of radius run (since we suppose that the line of each fibre is one metre long, taken at right angles to the plane of fig.

2), the tension of a fibre of the thickness, dr, would be $t\,dr$, and the result of the tension, $t\,dr$, which should be equal to $p_R - pr$, will be the sum of the quantities corresponding to $t\,dr$, taken between R and r. We have, then:

$$p_R - pr = \int_R^r t\,dr;$$

or,

$$-d(pr) = t\,dr. \qquad (a)$$

To this first relation between p, t, and r, is added a second, by the consideration of the diminution of the thickness of the fibres due to their compression. The compression of a piece of one metre would be $\frac{p}{E}$, E being the co-efficient of elasticity; the compression of a piece, dr metres in thickness, would, therefore, be $\frac{p}{E}dr$, or, in other words, if the metal be homogeneous, the total diminution of thickness between the radii, R and r, in their primitive state, must be,

$$\frac{1}{E}\int_R^r p\,dr.$$

We can obtain another equal expression of this total diminution of thickness. The original thickness was $r - R$. Now the circular fibre, the radius of which was originally r, and the length $2\pi r$, has been elongated by $\frac{t}{E}$ per metre run, and, consequently, by $2\pi r\frac{t}{E}$ altogether. Its length, at the present time, is, therefore, $2\pi r\left(1+\frac{t}{E}\right)$; and, as it remains circular, its radius is now $r\left(1+\frac{t}{E}\right)$. In the same manner the radius of the fibre, which was originally R, is now $R\left(1+\frac{T}{E}\right)$. The total thickness, then, which was $r - R$, in the primitive condition, has now become, after alteration of form,

$$r\left(1+\frac{t}{E}\right) - R\left(1+\frac{T}{E}\right);$$

and, consequently, the diminution of thickness is:

$$R\frac{T}{E} - r\frac{t}{E} = \frac{1}{E}\int_R^r p\,dr;$$

whence may be deduced:

$$-d(tr) = p\,dr. \qquad (b)$$

Let us develop the fundamental equations (a) and (b), first by adding them member to member, and then subtracting them, when we shall arrive at the results given in the following equations:

$$p\,dr + r\,dp + t\,dr = 0,$$
$$t\,dr + r\,dt + p\,dr = 0.$$
$$dt - dp = 0.$$
$$t - p = \text{const.} = T - P = T' - P'. \qquad (c)$$
$$2(t+p)\,dr + r(dt+dp) = 0$$
$$2\frac{dr}{r} + \frac{d(t+p)}{t+p} = 0$$
$$r^2(t+p) = \text{const.} = R^2(T+P) = R'^2(T'+P'). \qquad (d)$$

From the equations (c) and (d) may be deduced the following:

$$t = \frac{T-P}{2} + \frac{R^2}{r^2}\cdot\frac{T+P}{2} \qquad (1)$$

$$p = -\frac{T-P}{2} + \frac{R^2}{r^2}\cdot\frac{T+P}{2} \qquad (2)$$

which solve the question.

The diagram of the values of t and p, given in fig. 3, shows clearly how these

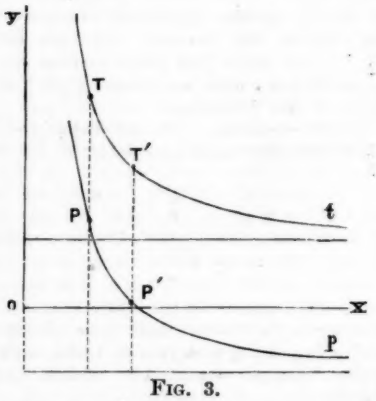


FIG. 3.

qualities vary when the radius varies. The curve (t) is of the hyperbolic class; it has for asymptotes, the axis of the y's

on one side, and on the other a parallel to the axis of the x's, at the height

$$y = \frac{T - P}{2}.$$

The curve (p) is identical with the preceding, but, taken parallel to the axis of the y's at a distance T — P below the former. It has then for asymptotes the axis of the y's, and the straight line

$$y = -\frac{T - P}{2}.$$

It follows that the fibre which is subjected to the greatest strain is that of smallest radius, that is to say, the inner fibre of the radius, R; and its tension is T. This granted, we can solve the following question:

Given: the inner primitive radius, R, *the pressures* P *and* P′, *and the limit of tension,* K; *to calculate the radius,* R′, *so that it shall not be exceeded at any point.*

From the equations (c) and (d) let us eliminate T′, which cannot serve us, and after reduction, and the substitution of the given limit, K, for the tension T, we shall obtain

$$R' = R\sqrt{\frac{K + P}{K - P + 2P'}} \qquad (3)$$

an equation which solves the question, and which proves that no thickness of metal would be sufficient (even if it were infinite) if the pressure, P, were to exceed K + 2 P′.

If we know the thickness which has been given to the metal in the case in which the cylinder has been able to resist great pressures, we may find, by means of the following equation, what is the true tension, K, borne by the fibre subjected to the greatest strain.

$$K = \frac{P\left(\frac{R'^2}{R^2} + 1\right) - 2P'\frac{R'^2}{R^2}}{\frac{R'^2}{R^2} - 1} \qquad (4)$$

2nd. *Cylinder. Great external pressure.*—Let it be understood that all the previous values are retained. We will not give here all the steps by which we have arrived at the relations (a) and (b); but will only remark that the tension which we before called t was an extension of the fibre; now, however, that it has become a compression instead, it changes its sign. Thus the equation (a) becomes:

$$-d(pr) = -t\,dr$$

$$d(pr) = t\,dr \qquad (a')$$

In the same way the equation (b) becomes

$$d(tr) = p\,dr. \qquad (b')$$

By adding these two equations member to member, we obtain

$$dp + dt = 0$$

whence

$$p + t = \text{const} = P + T = P' + T' \qquad (c')$$

By subtraction we arrive at:

$$r^2(t - p) = R^2(T - P) = R'^2(T' - P') \qquad (d')$$

Whence may be deduced:

$$t = \frac{T' + P'}{2} + \frac{R'^2}{r^2} \cdot \frac{T' - P'}{2} \qquad (5)$$

$$p = \frac{T' + P'}{2} + \frac{R'^2}{r^2} \cdot \frac{T' - P'}{2} \qquad (6)$$

The two curves, diagrams of the values of t and p, have still for common asymptote the axis of the y's; besides the straight line

$$y = \frac{T' + P'}{2}$$

is also a common asymptote, but the two curves are in symmetrical proportion with respect to this straight line. It will be seen, then (fig. 4), that: 1st, contrary to the preceding case, the transverse compression of the circular fibres continually diminishes from the exterior

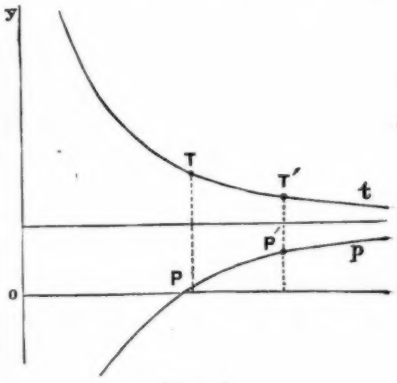


FIG. 4.

to the interior; 2nd, as in the preceding case, the longitudinal compression continually increases from the exterior to the interior. To put a limit, then, to the value K′, the longitudinal compression of the fibre subjected to the greatest strain, T must be made = K′ in the equations (*c′*) and (*d′*), and the compression T′ must be eliminated from them. We shall then be in a position to solve, without difficulty, the following question:

Given: the external primitive radius R′, *the pressures* P′ *and* P, *and also the limit of compression* K′; *to calculate the internal radius* R, *so that at no point shall this limit be exceeded.*

Let us remark, in the first place, that the co-efficient of calculation K′ may differ greatly from the co-efficient K, admitted for tensile strains. Generally it must be taken at a smaller value, because an alteration of form, begun on the outside, is more likely to be continued up to fracture. However that may be, when we have fixed upon this co-efficient, we shall have:

$$R = R' \sqrt{\frac{K' - 2P' + P}{K' - P}}. \qquad (7)$$

Since P represents a very slight pressure, it follows that the denominator of the fraction, the square root of which is to be extracted, is necessarily positive. As to the numerator, it would become zero if

$$P' = \frac{K' + P}{2}.$$

In this case the internal radius would be zero and therefore the piece solid, thus becoming removed from the conditions of the problem altogether. A higher value would render R imaginary. Consequently, P′ is limited to the value $\frac{K' + P}{2}$. *It will be remarked that this limit is considerably lower than that which is obtained in the case of the great pressure in the interior.*

3rd. *Sphere. Great pressure in the interior.*—We retain all the previous values; and the property, to which we before called attention with respect to an arc, is equally suitable to a hemisphere. It follows that the component of the pressures which act upon the interior of the hemisphere is equal to $P\pi R^2$. In the same way, for the sphere of radius r, the component is $p\pi r^2$. The difference $\pi(PR^2 - pr^2)$ is equal to the resultant of the tensions normal to the ring obtained by dividing the sphere in a diametrical plane. Now this tension is $t\,dr$ per linear metre of the fibre, which has a total length of $2\pi r$; the total tension of this fibre is therefore $2\pi r t\,dr$. Consequently, we have:

$$\pi(PR^2 - pr^2) = \int_R^r 2\pi r t\,dr,$$

whence $$-d(pr^2) = 2rt\,dr. \qquad (A)$$

As to the second relation, it is the same as in the corresponding case of the cylinder. We have then to deal with the two equations:

$$d(pr^2) + 2rt\,dr = 0 \qquad (A)$$
$$d(tr) + p\,dr = 0. \qquad (B)$$

The following transpositions lead to the result sought:

$$r^2\,dp + 2pr\,dr + 2rt\,dr = 0$$
$$r^2\,dt + tr\,dr + pr\,dr = 0$$
$$r^2(dp + dt) + r\,dr\,(p + t) = 0.$$
$$3\frac{dr}{r} + \frac{d(p+t)}{p+t} = 0 \qquad (C)$$
$$r^3(p+t) = \text{const.} = R^3(P+T) = R'^3(P'+T')$$
$$2\,dt - dp = 0$$
$$2t - p = \text{const.} = 2T - P = 2T' - P' \qquad (D)$$
$$t = \frac{2T-P}{3} + \frac{R^3}{r^3}\frac{T+P}{3} \qquad (8)$$
$$p = -\frac{2T-P}{3} + 2\frac{R^3}{r^3}\frac{T+P}{3} \qquad (9)$$

In fig. 5 are shown the diagrams of the

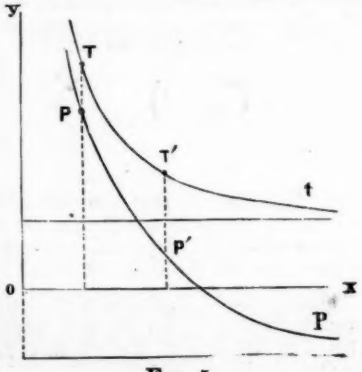


FIG. 5.

values of t and p. These are also hyperbolic curves, having for asymptote the common axis of the y's; each one has, besides, an asymptote parallel to the centre line of the x's at the height

$$y=\frac{2\,\mathrm{T}-\mathrm{P}}{3}$$

for the first, and a height equal, but of contrary sign, for the second. It will be seen that it is still the fibre of the radius R which is subject to the greatest strain by the expansion. This remark will then serve to solve the following question:

Given: the original internal radius R, *the pressures* P *and* P′ *and also the limit of tension* K; *to calculate the radius* R′, *so that at no point will the tension exceed this limit.*

From the equations (C) and (D) let us eliminate T′, and, after reducing, we shall obtain:

$$\mathrm{R}'=\mathrm{R}\sqrt[3]{\frac{2\,(\mathrm{T}+\mathrm{P})}{2\,\mathrm{T}-\mathrm{P}+3\,\mathrm{P}'}} \qquad (10)$$

It will be seen that if P were to exceed $2\,\mathrm{T}+3\,\mathrm{P}'$, there would not be sufficient thickness.

4th. *Sphere. Great external pressure.*— The reasoning which enabled us to construct the fundamental equations (*a*) and (*b*) applies to the preceding case, and we may be permitted to give the following equations without explanation:

$$d\,(p\,r^3)-2\,r\,t\,d\,r=0 \qquad (\mathrm{A}')$$

$$d\,(t\,r)-p\,d\,r=0 \qquad (\mathrm{B}')$$

$$r^3\,dp+2\,p\,r\,d\,r-2\,t\,r\,d\,r=0$$

$$r^3\,d\,t+t\,r\,d\,r-p\,r\,d\,r=0$$

$$r^3\,(d\,t-d\,p)+3\,(t-p)\,r\,d\,r=0 \qquad (\mathrm{C}')$$

$$r^3(t-p(=\text{const.}=\mathrm{R}^3(\mathrm{T}-\mathrm{P})=\mathrm{R}'^3\,(\mathrm{T}'-\mathrm{P}')$$

$$r^3\,(2\,d\,t+d\,p)=0$$

$$2\,t+p=2\,\mathrm{T}+\mathrm{P}=2\,\mathrm{T}'+\mathrm{P}' \qquad (\mathrm{D}')$$

$$t=\frac{2\,\mathrm{T}'+\mathrm{P}'}{3}+\frac{\mathrm{R}'^3}{r^3}\cdot\frac{\mathrm{T}'-\mathrm{P}'}{3} \qquad (11)$$

$$p=\frac{2\,\mathrm{T}'+\mathrm{P}'}{3}+\frac{\mathrm{R}'^3}{r^3}\cdot\frac{\mathrm{T}'-\mathrm{P}'}{3} \qquad (12)$$

The two curves, diagrams of the values t and p, have also, for common asymptotes, first the axis of the y's, and then the straight line

$$y=\frac{2\,\mathrm{T}'+\mathrm{P}'}{3}.$$

These are represented by Fig. 6, which

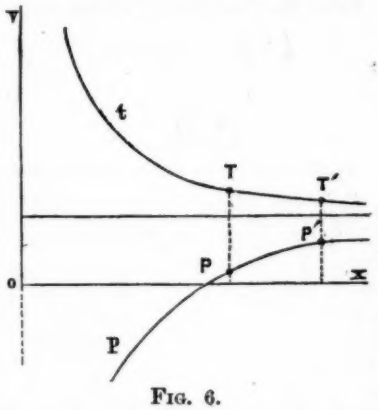


FIG. 6.

proves that the greatest tension, which is here a compression, takes place in the interior, at the smallest radius R. It is, then, also in this case, T, which must be made equal to K′, the safe compressive strain. By eliminating T′ from the equations (C′) and (D′) we shall have the following formula:

$$\mathrm{R}=\mathrm{R}'\sqrt[3]{\frac{2\,\mathrm{K}'+\mathrm{P}-3\,\mathrm{P}'}{2\,(\mathrm{K}'-\mathrm{P})}} \qquad (13)$$

which serves to solve the following problem:

Given: the external radius R′ *and also the external and internal pressures* P′ *and* P; *to calculate* R, *so that tension should at no point exceed the limit* K′.

Since the internal pressure P is small, the denominator $\mathrm{K}'-\mathrm{P}$ is necessarily positive, therefore the external pressure must be lower than the value which made the numerator negative, that is to say:

$$\frac{2\,\mathrm{K}'+\mathrm{P}}{3} \qquad (14)$$

If P had the value (13) the internal radius would be zero, and the sphere would no longer fulfil the desired conditions.

Let us now solve the following problem:

Knowing the thickness of a dam which has successfully resisted great pressures,

to find the maximum true tension, T, *which the fibre subjected to the greatest strain has borne.*

From the equation (13) we deduce that:

$$T = \frac{\left(\frac{R'}{R}\right)^2 (3P' - P)\, 2P}{2\left\{\left(\frac{R'}{R}\right)^2 - 1\right\}} \qquad (15)$$

Application of the preceding formulæ.

Cylinders of slight thickness, but subjected to great internal prssure.—Under this head may be mentioned: steam pipes, the cylinders of steam engines, steam boilers and their pipes, and gas and water pipes. In the case of boilers, the Government regulations require the application of a formula which supposes the resistance of wrought iron to be 2½ kilogrammes per square millimetre (3555 lb. per square inch), but which contain a constant, to be added for the purpose of covering certain influences not taken into account in the calulation. This formula is therefore, in other words, a purely experimental one. The same may also be said of those which are employed for the calculation of the thickness of steam cylinders, &c., in which one always meets with a constant, determined experimentally. The fact is that this thickness, minimum thickness though it be, should be sufficient not only to resist the pressure of the steam in the cylinder when finished, but also to facilitate the moulding and casting, in order that these operations may be performed both surely and economically. To apply our formula (3) in this case would, then, be superfluous; besides the result would differ but little from that given by the following well-known formula:

$$e = R\frac{P}{K}.$$

In fact, with 0.3 metre (11.81 in.) internal radius and a difference in pressure of 6 atmospheres, taking the resistance as 1½ kilogramme per square millimetre (2133½ lb. per sq. in.), we find, by the common formula, without constant, $e = 0.012$ m. (.472 in.); and by our formula (3), $e = 0.0125$ metres (492 in.). The difference is too slight to be taken into account, the error committed being imperceptible. But the case, in which the error should be rectified, is, when the great pressure bears a high ratio to the co-efficient of resistance, K; and, consequently also, the thickness of the cylinder bears a high ratio to the radius. This case occurs in hydraulic presses.

Cylinders of great thickness, with great internal pressure.—The above mentioned formula, at which we arrived by supposing that the tension of the circular fibres is uniformly distributed over the whole thickness of the metal, when it is applied to the case of a hydraulic press, might lead to absurd and even dangerous results—absurd, because it induces the supposition that however great may be the pressure, and whatever may be the resistance of the metal, there exists a certain thickness sufficient to prevent the fracture of a vessel; and dangerous, because it gives no information as to the pressure to be taken as the limit that a given metal will bear. The following examples will justify what has been laid down:

Scientific writers admit generally that the *co-efficient of resistance* of cast iron to tensile strain, is 600 kilogrammes per square centimetre (8534 lb. per square inch), and that, in practice, the co-efficient of calculation should be equal to the co-efficient of resistance divided by a co-efficient of safety, which should never be less than unity. However, in the case of hydraulic presses, 600 is admitted as a suitable figure for resistance in calculating the thickness. Now let us admit that the given internal pressure, P, be also 600 kilogrammes per square centimetre, and that the internal radius, R, of the press be 0.15 metre (5.9 inch). The above formula will give:

$$e = 0.15^m \times \frac{600}{600} = 0.15^m$$

$$R' = R + e = 0.3^m = 2R.$$

As the exterior pressure, P′, is about 1 kilogramme per square centimetre (14.2 lb. per square inch), while P = 600 kilogrammes per square centimetre (8534 lb. per square inch), we will omit P′ from our calculations, in the presence of P, and make use of the following formulæ in place of (3) and (4).

$$R' = R\sqrt{\frac{K + P}{K - P}} \qquad (3)_A$$

$$K = P \frac{\left(\frac{R'}{R}\right)^2 + 1}{\left(\frac{R'}{R}\right)^2 - 1} \qquad (4)_A$$

If in the preceding case we make $R' = 2R$, let us see what, in reality, is the tension of the inner ring of the press. The formula (4) A gives:

$$K = 600 \frac{4 + 1}{4 - 1} = 1000.$$

The inner fibre, then, that is subject to the greatest strain, undergoes a tension which might be considered dangerous in reality, and which must consequently receive an appreciable permanent alteration.

In accordance with the formula (3) A, if we were to make $K = P$, we should find R' infinite. But if we have been able to construct presses, which have actually borne, without injurious result, a tension of 1000 kilogrammes per square centimetre (14223.36 lb. per square inch), let us admit that this co-efficient may be employed in our formulæ, and let us see what we shall arrive at in the case in which the pressure, P, though less than 1000 kilogrammes per square millimetre, exceeds 600; for instance, let us make $P = 800$, and let us calculate R' by the two methods:

Ours gives—

$R' = 0.45$ metre $= 1.47$ ft., and $e = 0.3$ metre $= 11.81$ in.

The other—

$R' = 0.35$ metre $= 1.14$ ft., and $e = 0.2$ metre $= 7.87$ in. But if the latter thickness be adopted, the internal tension would be 1160 kilogrammes per square centimetre (about 16.499 lb. per square inch), a strain which the cast iron could not bear with safety.

For a pressure of 900 kilogrammes per square centimetre (12801.02 lb. per square inch), our formula would give $e = 0.504$ metre (1.65 ft.); and the other, $e = 0.225$ metre (8.85 in.); by adopting this last formula, we should find that the actual maximum tension is 1243 kilogrammes per square centimetre (17,679.63 lb. per square inch).

Cylinders of slight thickness, with great external pressure.—Boiler tubes, used as flues, come under this category. If the external pressure be not great, the difference between the results of the formula

$$e = R' \frac{P' - P}{K' + P' - P}$$

usually employed, and that, (7), which we have demonstrated, is not worth while taking into consideration in practice. Thus, for $P' - P = 6$, and $K = 200$, we find, by the foregoing formula,

$$e = 0.029\ R',$$

and by ours,

$$e = 0.031\ R',$$

giving a difference of only a few decimals of a millimetre, in the case of tubes of 0.6 metre (nearly 2 ft.) in diameter. It is no longer the same, however, when the pressure bears a considerable proportion to the resistance, as we shall proceed to show.

Cylinders of considerable thickness, and with great external pressure.—This case occurs in the tubbing to shafts, especially when the pressure of water is great. Supposing that the strain is uniformly distributed over the whole thickness, we arrive at the formula:

$$R' = R \frac{K' - P}{K' - P'}$$

R' and P' being the radii and the external pressures. Our method gives the following:

$$R' = R' \sqrt{\frac{K' - P}{K' - 2P' + P}}.$$

The internal pressure, P, is that of the atmosphere. We will suppose it to be 10,000 kilogrammes per square metre (14.223 lb. per square inch).

It seems that we can apply the first of these formulæ to the calculation of the thickness of tubbing, by making:

	Kilogrammes per square metre.		Lb. per square inch.	
K' =	120,000	=	170.68	for brick.
K' =	450,000	=	640.05	for oak.
K' =	800,000	=	1137.86	for stone.
K' =	4,000,000	=	5689.34	for cast iron.

Now the limit of the value of P' will be K', in accordance with the first formula, and $\frac{K' + P'}{2}$ in accordance with the second. If, then, we estimate the pressure, P', in respect to the height of water, we shall have for limit of height of the

column of water pressing on the tubbing :

	Brick.	Oak.	Stone.	Cast Iron.
In accordance with the first formula.....	120	450	800	4000 met.
	393.7	1476.4	2624.7	13123.5 ft.
In accordance with the second formula.	65	230	405	2005 met.
	213.2	754.6	1328.7	6578.2 ft.

So long as the pressure of water does not approach these limits, it is a matter of indifference which formula be employed ; but this is by no means the case when the limits are approached, as the following table will show. Having calculated the value $\frac{R'}{R}$ for the brick, the oak, and the stone, for a column of 60 metres (196.85 ft.); then for the oak and stone, for a column of 200 metres (656.17 ft.); and lastly, for the stone, in the case of a column of 350 metres (1148.31 ft.), we obtain :

	Bricks.	Oak.	Stone.	Oak.	Stone.	Stone.
Value of H.....	Metres. 60	Metres. 60	Metres. 60	Metres. 200	Metres. 200	Metres. 350
$\frac{R'}{R}$ according to 1st formula.	1.833	1.1283	1.0675	1.76	1.3167	1.7556
$\frac{R'}{R}$ according to 2d formula.	3.31	1.1376	1.07	2.707	1.388	2.68
Thicknesses for R=1½ *metre.*						
	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.
According to 1st formula..	1.25	0.192	0.101	1.14	0.475	1.133
According to 2d formula...	3.465	0.206	0.105	2.561	0.583	2.520
Thicknesses for R=4 *metres.*						
	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.
According to 1st formula..	3.333	0.513	0.270	3.040	1.267	3.022
According to 2d formula...	9.240	0.551	0.280	6.828	1.552	6.720

If we adopt the thicknesses given by the first formula, we shall be in a position to calculate the true value of K′, according to the second formula. This value of K′ is independent of the value of R, and depends only upon the ratio adopted for $\frac{R'}{R}$. We shall have, then :

True value of the maximum Tension.

Kilogrammes per square metre.

153,000 | 480,000 | 830,000 | 571,000 | 908,000 | 1,018,000

Lb. per square inch.

217.61 | 682.73 | 1180.53 | 812.15 | 1291.48 | 1447.9

It will be found preferable, in the case of very deep shafts, to make use of cast iron. If, for instance, the tubbing be subject to the pressure of a column of water of the height of 800 metres (2624.71 ft.), by taking K′ as representing 4,000,000 kilogrammes per square metre, we shall have :

In accordance with the first formula,

$$\frac{R'}{R} = 1.247$$

In accordance with the second formula,

$$\frac{R'}{R} = 1.287$$

For R = 1½ metre (4.92 ft.), the thickness would be, in accordance with the first formula, 0.37 metre (1.21 ft.), and, in accordance with the second, 0.43 metre (1.41 ft.).

The maximum tension to which

cast iron is subjected, if we calculate the ratio $\frac{R'}{R}$ in accordance with the first formula, comes out so high as 4,437,000 kilogrammes per square metre (6310.9 lb. per square inch), a figure which we must regard as too high. However, it must be admitted that a thickness of cast iron as great as 0.43 (1.41 ft.) is excessive, and the cost of such tubbing would be unusually high. Besides, in practice, a higher co-efficient of calculation than 4,000,000 has been employed. As a matter of fact, in the Carling Pit, a thickness of only 0.045 metre (1.771 in.) has been given to a cast-iron tubbing of the radius of 1.68 metre (about 5 ft. 6 in.), and that at a depth of about 165 metres (541.34 ft.). We have, then, in this case—

$$\frac{R'}{R} = \frac{1.725}{1.680} = 1.02678$$

$$\left(\frac{R'}{R}\right)^2 = 1.054277$$

$$\frac{P'}{P} = 16.5$$

and, in accordance with the second formula—

$$K' = 6{,}031{,}444.$$

Now if, in the preceding example, we were to give to K' this value we should find, in accordance with the second formula, that—

$$\frac{R'}{R} = 1.1644$$

whence $R' = 1.747$ metre (5.731 ft.)

and $e = 0.247$ metre (9.724 in.)

a thickness which is still very great, but which, at the same time, it would be dangerous to diminish, when the pressure is so enormous.

Hollow sphere, of considerable thickness, with great external pressure.—Spherical or Saxon dams come under this head.

When it may be supposed that the tension is regularly distributed over the whole surface, we arrive at the following formula :

$$R' = R\sqrt{\frac{K'}{K' - P'}} \qquad (a)$$

in accordance with which the limit of pressure will be equal to K'. Our formula (13) gives :

$$R' = R\sqrt{\frac{2(K' - P)}{2K' - 3P' + P}} \qquad (b)$$

which proves that the limit of pressure is—

$$\frac{2K' + P}{3} \qquad (c)$$

The limits in height, therefore, of the columns of water would be :

	Brick.	Oak.	Stone.
In accordance with (a), in metres	120	450	800
In accordance with, equivalent in feet	393.7	1476.4	2624.7
In accordance with (c), in metres	83	303	537
In accordance with, equivalent in feet	272.3	994.1	1761.8

An oak dam, subject to a pressure of 240 metres (787.41 ft.) of water, and the inner radius of which was $R = 7$ metres (nearly 23 ft.) should, therefore, have a thickness :

In accordance with formula (a),

$\frac{R'}{R} = 1.4637$ $\quad e = 3.246$ metres.

In accordance with formula (b),

$\frac{R'}{R} = 1.6663$ $\quad e = 4.664$ metres.

If we make the thickness 1.7 metre (5.577 ft.), we shall find, in accordance with formula (15), that the maximum pressure may be as high as 730,000 kilogrammes per square metre (1038.29 lb. per square inch).

The thickness of a spherical wood dam, constructed in Saxony, to resist a column of water, 200 metres (656.17 ft.) high, with an inner radius of 6½ metres (21.325 ft.), was 1.883 metre (6.177 ft.).

It follows that the maximum tension, calculated by formula (15), is, in this case :

$K' = 543{,}500$ kilogrammes per square metre (773.03 lb. per square inch.)

These examples are sufficient to show that engineers are by no means agreed as to the co-efficients of safety, to be employed in calculations respecting works of this kind ; and that, generally, the tension to which such structures are actually subject is greater than was supposed.

EXPRESSION IN ARCHITECTURE.

From "The Building News."

It is not unusual to hear a person exclaim, "How heavy that building is, or how light! it is more fit for a prison, or it has the look of a music-hall." Such opinions comes from those who are perfectly ignorant of what architecture is, as well as from others critically conversant with the art. However unintelligible the language of architecture may be to the uninitiated, these outer forms of expression are well understood by the majority of them at least. In our times, however, a kind of spurious expression is admitted. Thus we hear of such-and-such a building spoken of as having too much of the club-house character, or as being too like a church, simply from the association accidentally attached to those structures. An able writer on design has well stated this fallacy of confounding the few causes of expression in architecture with association. The ideas of expression which the uninitiated majority—and, indeed, all who are capable of perceiving distinctions—have are totally different from the ideas which a sentimental study of art invokes. These last are based really on a very superficial study of a few examples without going any deeper. The writer alluded to says "It is most important for all who attempt to practice or understand this art to be perpetually on their guard against the insidious attacks of this error, the mistaking (*i. e.*, *acquired*) expression for that which is natural, and therefore permanently true. I cannot but consider this the chief source of the acknowledged great utility of travel to the architect. Its use is not to show him much of the world, but to teach him how little of it he has seen. Nothing but the emancipation from narrow local prejudice will set a man thinking and searching in earnest to distinguish what is local and accidental, in beauty and expression, from what is universal and essential." Just now there seems to be a greater prevalence of this false estimate of design, and architects and writers generally appear to fall into the same mistake in distinguishing buildings. It is a species of hypercriticism that has become the bane of *soi-disant* critics, and some amateurs. It smacks of a meagre acquaintance with a few examples, instead of a generalized study of all styles. Thus the first adverse critics indulged in lampooning porticoes to churches *because* they were first used in front of heathen temples, as another set stigmatized the earlier works of the Gothicists forasmuch as they recalled mediæval superstition. It was not uncommon for the critics of forty years ago to apply all sorts of pseudonyms and sobriquets to any buildings that savored too much of some typical or well-known example, as if the resemblance detracted from the merit of the composition as a whole. To be brief, we must spurn this kind of comparison if we are to benefit at all in an age essentially electric like the present. What matters if a building is adorned with a cupola too much like those which crown the facade of Wilkins's National Gallery? They may look "pepper-casters" upon the aforesaid structure, but it would be unwise, as well as foolish, to denounce the adaptation or even copy of one of them as too much like a pepper-box if it suitably met the conditions of a new structure. To apply this kind of stricture is not at all to the point, however clever and smart it may appear. Unfortunately art-writers are a little too much addicted to the "sensational," too fond of conjuring up likenesses, however far-fetched, and flavoring their remarks with illustrations and analogies that unfortunately often cut as much one way as another. There is one excuse for this, however: it is an easy way of dealing with a dislike when more substantial reasons cannot be adduced. Architectural or art disquisitions would be sometimes a little wearisome, and too much like theological subtleties for the easy digestion of most people, if examples were not given; but let them, at least, be well chosen. Architectural expressions, then, are considerably narrowed when we have struck out these spurious ones—in fact, they cannot for a moment be considered so numerous as the multitudinous wants of

all our buildings—that is to say, it would be absurd to suppose there was an expression suitable to each kind of building. If our domestic buildings are sometimes like convents, and occasionally like club-houses, there is nothing to complain of, for individual tastes are equally as diverse. Neither should we be so fastidious as to censure the proclivities of church-builders, who in one instance embodied the extremest sacrificial type of plan, and in another the congregational auditorium. These are differences for which there are ample apologies to be found, and yet in both cases our ideas of true art expression would be shocked if these extreme religionists carried their tenets so far into the fabrics as to violate what would be considered to be proper architectural adaptations in plan or external features. Thus it is possible to admit a certain degree of diversity into our designs, even if we appear to trespass upon the character of other buildings so long as we confine ourselves to justifiable expressions.

Let us here consider for a moment the range of these architectural expressions, and how far we may make them intelligible. Mr. Fergusson, in his "Essay on the principles of Beauty in Art," divides the arts into five classes: the technic, as carpentry; the technic and æsthetic, as plain architecture and gastronomy; the technic, æsthetic, and phonetic, as sculpture; the æsthetic and phonetic, as poetry; and the phonetic simply, as rhetoric. This ingenious classification embraces all the arts. To the highest class of architecture this author awards equal proportions of the three merits—that is to say, of technic or mechanical merits; æsthetic or those giving pleasure; and phonetic, those capable of telling a tale. But the author says this is only the case when architecture *per se* is connected with sculpture or painting, and the Greek architecture is selected as fulfilling this condition. As justly observed by Mr. Garbett, the system, however ingenious, fails to show in what respect the architect is superior to the picture-frame maker or the cook, and the same writer points to an intermediate kind of expressiveness in architecture—one that is capable of doing more than simply please by exciting different emotions, and yet incapable of speech. This kind of "dumb expression," as he terms it, is common to all the fine arts; we see it in architecture as well as in instrumental music. It is a language common to all the arts of form and sound—it appeals to everybody alike, there can be no ambiguity about it. The pyramids and Temples of Egypt convey an impression that cannot be mistaken of one extreme kind, while the ærial fancies of the Arabs or the cunning artifice of the Hindoo palace or temple are equally apparent in awakening a different impression. Thus, after looking at the ruins of Karnac, with their massive forms based upon the square and circle, a sense of majesty or solemnity steals over us; not like the impression felt upon viewing a mediæval cathedral or that awakened by the splendid remains at Delhi. One over-awes by its mass, the other captivates. But we may illustrate three or four well distinguishable expressions of great historic periods. There are those represented by Thebes, Athens, Rome, and mediæval Europe, all well marked—that is, the impressions or feelings they are calculated to convey or arouse apart, from association, are readily defined in language. Thus awe in the first, majestic repose in the second, grandeur and sumptuousness in the third, and aspiration in the fourth are well understood sensations, which none but the most deadened to art influences can fail to have experienced. If we inquire we should find the greatest ignoramus was influenced by those works of architecture in the same or nearly in the same degree as the educated, showing that associations have nothing whatever to do with these broad and simple forms of expression. But let us next inquire into some of the sources of these various effects. Unfortunately there have been various deadening influences, such as association and the indiscriminate employment of different styles as the fashion of the day leads, which have dulled our perceptions; and so, if a gentleman wishes to build a country residence, any of the styles or expressions we have indicated may be used just as well as any other, regardless of the occupant's tastes and feelings' and at variance with the scenery. Expression is not studied by the architect, because his pet style is adopted and carried out

in accordance with his own idea—that is to say, if a regular-featured Classic kind of exterior was best adapted it would be ten to one rejected for a broken picturesque house; and, where irregularity of outline and sharp contrasting features would be a charm, a regular or placid-looking edifice would be designed. Now, the true avocation of an artist, rightly so called, and we presume every architect believes himself to be one, is an ability to convey an impression—not any sort, but the right one in the right place—just as he may use his pencil in conveying an expression of countenance or giving a clear idea of a portrait or a group of figures by a few well-understood touches. Above all things an artist, like a rhetorician, should be enabled to convey an impression in the shortest way. He should make the study of form and color or sound, in their various effects upon the eye or ear and, through it, to the sympathies and feelings, the great one; he, in fact, should become a physician in the art of allaying and soothing and giving pleasure or excitement to the emotions, or of swaying them in a pleasing manner. If he cannot do this he is no artist, and if he prescribes the wrong style he is unskillful, if not an impostor. The alphabet of expression consists of but a few characters. We have rectangular forms, or those in which the horizontal lines are continuous, and the vertical discontinuous, as in the Greek styles of composition. "A severe purity reigns supreme." Such an expression may be found in the Grecian Doric, and it appeals to the soberer qualities of the mind. In the Roman and Palladian we find a milder repose. The vertical features are more prominent and less massive, and circular and angular features break the extreme simplicity of the Greek composition. Under Scamozzi and the Venetian artists we find the curved or circular forms breaking still more into the severe rectangular treatment of the Greeks, as in the Vandramini Palace, Venice. Here the voids encroach largely upon the solids or walls, and if we study the Venetian palaces we shall find the arcade and the fenestration as conspicuous as the solid portions. In the court of the Ducal Palace, and in the earlier semi-Renaissance, a playful picturesqueness prevails. In the first building the introduction of the arch and the panelling of the piers gave a light and playful expression to the facades, and this is increased by the admixture of semi-circular and pointed arcades. Again, we have an inviting and extremely elegant expression in the Palladian style, as we see it in the Barbarano Palace, at Vicenza, and in the arcaded fronts of the Vicentine basilica. The superimposed orders, so favorite a treatment of Palladio, eminently suggest a festive and domestic expression—one admirably fitted for civic and palatial purposes no less than for buildings destined for music and the drama. Now, in both these extreme expressions of the Classic school, a repose though of different degrees prevails, the features and architectural lines all partaking of a contrast, rather of gradation than of suddenness. The angles, for instance, are generally right angles or obtuse ones, suggesting ideas of sublimity and repose rather than energy and unrest, as in the Pointed styles. In the latter the forms are more angular, the lines meet at sharper angles, indicating rigidity and energy; thus the vertical features of buttresses and shafts rise uninterruptedly; no horizontal members disconnect them or stop them, as we find in the column and entablature of the Classic orders; the buttresses spring beyond the bounding lines of the building and terminate in pinnacles, and these converge in their turn to points. Again, in the pointed windows and the spire the same piercing energy or character is seen; their angular apices and points indicate an upward growth—a dynamic rather than static condition: the whole composition, indeed, of such an edifice as Salisbury or Amiens Cathedral is one suggesting energy and force, not repose. We may briefly enumerate a few of the abstract principles upon which architectural expression depends. Alison and other writers on the subject have agreed upon certain kinds of form which suggest ideas to the mind. Thus angular forms and lines express strength, energy, and force; the same qualities produce strong contrasts of light and shade on surfaces, and these sharp transitions characterize rocky scenery and Gothic buildings. The contrary

kinds of form—those that are curvilinear and winding, and which give rise to gradation of light and shade—indicate delicacy, ease, grace, and refinement, and characterize the Italian modes of Classic treatment. The Greek character, as seen in the Greek Doric, shows a combination of these opposite forms: we get the square and circular forms combined as in the Doric order. In the Roman styles the curvilinear and rectilinear are equally blended, producing grandeur and richness of expression; and in the Gothic forms they are again united, though the angular forms are predominant. In one extreme we have contrast, expressive of grandeur, force, and exciting qualities, and in the other extreme of gradation, elegant and soothing qualities. The architect should be master of these combinations, and be able to apply such varieties of form as will best conduce to a particular expression. Unlike painters and sculptors, architects are the professors of abstract design, and, as we have said, should be able to discover the general laws of expression in the same manner as the physicist does with inert matter. Another principle well worth noticing is the proportion of opening to solid wall in our buildings; and we dwell upon it here as it has scarcely been noticed by other writers. We have styles in which the wall is everything, and others in which the openings dominate over the design. In the Greek, the openings were merely apertures compared with the wall; but in the Venetian Italian it becomes a framework only—so extreme is the difference. In the Early Gothic the windows are mere piercings and slits in the walls; but in the Latter Gothic—the Perpendicular, for instance—they occupy by far the largest area, the wall spaces being reduced to attenuated piers or mullions. This principle is indiscriminately applied by architects, as we see in churches. In one, we find all windows in the clerestories and aisles, in another, all wall space. It is generally an excess of one or the other that is to be condemned. If the admission of light had anything to do with it we would not complain; some architects prefer "a dim religious light," and to this they conform their design. But the principle has a great deal to do with expression also; a windowless building like Newgate prison has a forbidding expression, a repelling character not unsuited in that case; but a building full of windows has an inviting cheerful aspect no one can mistake. The Italian schools illustrate not only the formal principles of expression we have enumerated, but this one of lighting also. Thus, in the Florentine, there is scarcely any arcuation, though the style is astylar; windows bear a small proportion to the wall space, while, in the Venetian schools, arcuated effects are largely used, and the window is an important feature. The Roman holds a kind of intermediate ground between these two. In the Florentine we have almost Doric simplicity and severity in the structural features; in the Roman a more varied treatment; and in the Venetian highly broken lines, large windows, and picturesque features. As an English style for country residences, and when ample light and cheerful expression are wanted, the Venetian is best suited, and it has been largely adopted by the English architects of the Renaissance; for town and civic structures, in which a severer expression is required, the Florentine or the Roman is better adapted. In the Gothic styles we have quite as large a range to choose from. Of course, in regard to windows, lighting must always be mainly regarded, though these may be expressed variously, and the architect may always give his buildings their own suitable expressions by selecting the proper formal element of those we have referred to.

AIR-SHIP FOR MAIL SERVICE.—A German inventor, Mr. William F. Schroeder, of Baltimore, is said to have submitted to the New York Engineers' Association a model of an air-ship, designed for carrying the mails between America and Europe. The air-ship is to be steered by a hydraulic apparatus of eight horse-power, and to be carried by a gas balloon. The ship weighs 2,800 lb., and has a carrying capacity of 12,000 lb.; its minimum rate of progress is estimated at seventy miles an hour. Experiments are now being made with it: should they be successful, a proposal will be made to Congress to intrust the mail service to air-ships.

TEST OF HOWARD BOILERS AT THE FAIR OF THE AMERICAN INSTITUTE.

By THERON SKEEL.

I.

SIR: The Committee appointed by the Managers of the American Institute Fair for the test of the Howard Boilers, on exhibition there, beg leave to inform you of the details of the test decided upon as follows:

The test will commence on the afternoon of the 17th, and will last twenty-four hours.

Anthracite coal of good quality will be furnished by the Institute in sufficient quantity. The weight of coal consumed by the boiler will be noted as nearly as possible as it is fed into the furnace.

The ashes and refuse will be weighed dry.

The boiler will be fed by an injector with cold feed water from a tank, and the volume noted half hourly.

During the first twelve hours the steam will be maintained as nearly as possible at 250 lbs. pressure per square inch, and during the latter twelve hours at 75 lbs. per square inch above the atmosphere.

The temperature of the steam will be noted by a mercurial thermometer in the steam drum or near it.

A portion of the steam, probably about 10% will be condensed in a worm surrounded by cold water, and the weight and temperature of the steam so condensed together with the weight and temperature of the condensing water at injection and discharge will be noted. These measurements will give the means of computing accurately the amount of priming, or the degree of superheating of the steam so condensed. It will be *assumed* that the balance of the steam which will be allowed to escape from the safety valve is of the same quality.

The temperature of gas in the chimney will be measured by a thermometer in a sand bath placed in it.

The boiler will be fed by an injector, the water being maintained as nearly as possible at the same level. If practicable, a *steady feed* shall be kept on the boiler.

You will be at liberty to select your own firemen, and to have control of the fire during the experiment, provided the Committee do not wish to replace them by their own men, it being distinctly understood that the Committee reserve the right to assume control of the fires at any moment when they should think proper to do so.

It is the wish of the Committee to leave the charge of the fires entirely in your hands, and they will only interfere if they consider the uniformity of the experiment is being injured by very irregular firing.

The rate of combustion will be, if possible, 12 lbs. of coal per square foot of grate per hour or greater.

The keeping of the log of the experiment will be done by the Committee or their assistants.

The Committee would like to have you send them tracings of the boiler and the manner of setting, and of such details as you may think proper, in order that they may compute the grate surface, heating surface and calorimeter, and notice the peculiarities in their report. They would be glad to receive these tracings at once.

The second boiler from the south end has been selected for trial, because it is near the chimney and has the ordinary form of grate.

The connections of the other boilers with the flue will be closed during the experiment.

The Committee will expect to receive notice from you that you are satisfied with these conditions before commencing the experiments.—Very respectfully,

THERON SKEEL,
Judge, Group I., Div. V., for the Committee.

JUDGES' REPORT.

NEW YORK, Feb. 5, 1875.

To the Board of Managers:

Gentlemen,—After full and impartial examination of the Howard Sectional

Safety Boiler the undersigned Judges make report that there were two kinds of boilers exhibited by this company, the one being set in brick-work and provided with grates, feed and blow-pipes, safety valve and all appurtenances ready for use, and that this boiler was used to provide steam for warming the building and running the machinery during the time the fair was open; the other being only a few sections of tubes not set in brick-work, but intended for exhibition only. Your committee understand that this last pattern was the form of boiler now manufactured by the exhibitors, being a recent improvement since the others were set up in the fair, and feel themselves at liberty to consider this last form as entitled to the award, although the experiments for economy and efficiency were made on the older pattern.

The following description applies to both forms of boiler:

The water and steam are contained, as in most of the class to which it belongs, *within* wrought iron tubes while the products of combustion are in contact with the outside.

The original motive, no doubt, for introducing the class of boiler was to obtain the necessary strength to resist the high pressure of steam now coming into almost universal use, without resorting to very thick shells.

The forms generally used previous to the introduction of sectional boilers were for stationary purposes, cylindrical shells containing either tubes or flues, set in brick-work and absorbing heat both from the outside through the shell and on the inside through the tubes or flues; and for marine purposes, of an iron shell having an appropriately rectangular section and containing several furnaces and sets of either fire or water tubes. These forms of marine boilers have now generally been superceded by those having cylindrical shells of large diameter containing several cylindrical furnaces and a sufficient number of horizontal fire tubes.

Notwithstanding such boilers are in general use they have many disadvantages and are probably soon destined to be supplanted by another form.

The stationary boilers have been in part supplanted by the Howard and other forms of sectional boilers, and your committee are encouraged to make a careful report on the Howard boilers in the exhibition by the facts that there is a large demand for the best boiler of that class, and that the results of the experiments and examination may assist both the manufacturers and the consumers.

The following excellent description from a technical journal applies to the later form of Howard boiler:

"As will be seen from the views we give the boiler is like the former Howard boiler, composed of wrought iron tubes 9″ in diameter externally, these tubes being connected together in groups, and being placed at a slight angle with the horizontal, several tubes of each group lying one over the other."* It will be remembered that in the horizontal tube boilers, until lately made by Messrs. Howard, the several tubes of each group are connected by one end only.

"In the new type, however, connections are provided at both ends, a decidedly better arrangement. Referring to the engravings and particularly to the detailed cuts it will be seen that each tube has fixed to it at each end a cast iron cap or chamber. The manner in which these caps are fixed to the tubes is somewhat peculiar. Around each tube at each end is placed a thin wrought iron hoop and holes are punched through this hoop, and the body of the tube. The tube end, properly cleaned, is then placed in the mould and the cast iron cap cast upon it, the metal running through the punched holes as shown in Fig. 1."

"To perfect the joint the wrought iron hoop, which as shown, projects slightly beyond the casting, is calked all round the tube. Messrs. Howard assure us that these joints stand well and give no trouble. The mode of attachment is certainly a simple one, and the introduction of the wrought iron calking strip is ingenious."

"To connect the superimposed pipes forming each section, the end caps or chambers are provided with nozzles turned slightly conical externally, these nozzles entering wrought iron junction rings bored out conically to receive them. The arrangement is shown clearly in the upper part of Fig. 1. From which it

* ("Engineering," July 24, 1874.)

will be seen that the nipples on the cast iron cap take their bearing entirely against the conical surface of the wrought iron junction rings, and do not butt against each other. * * * * * The series of caps are drawn tightly together by a

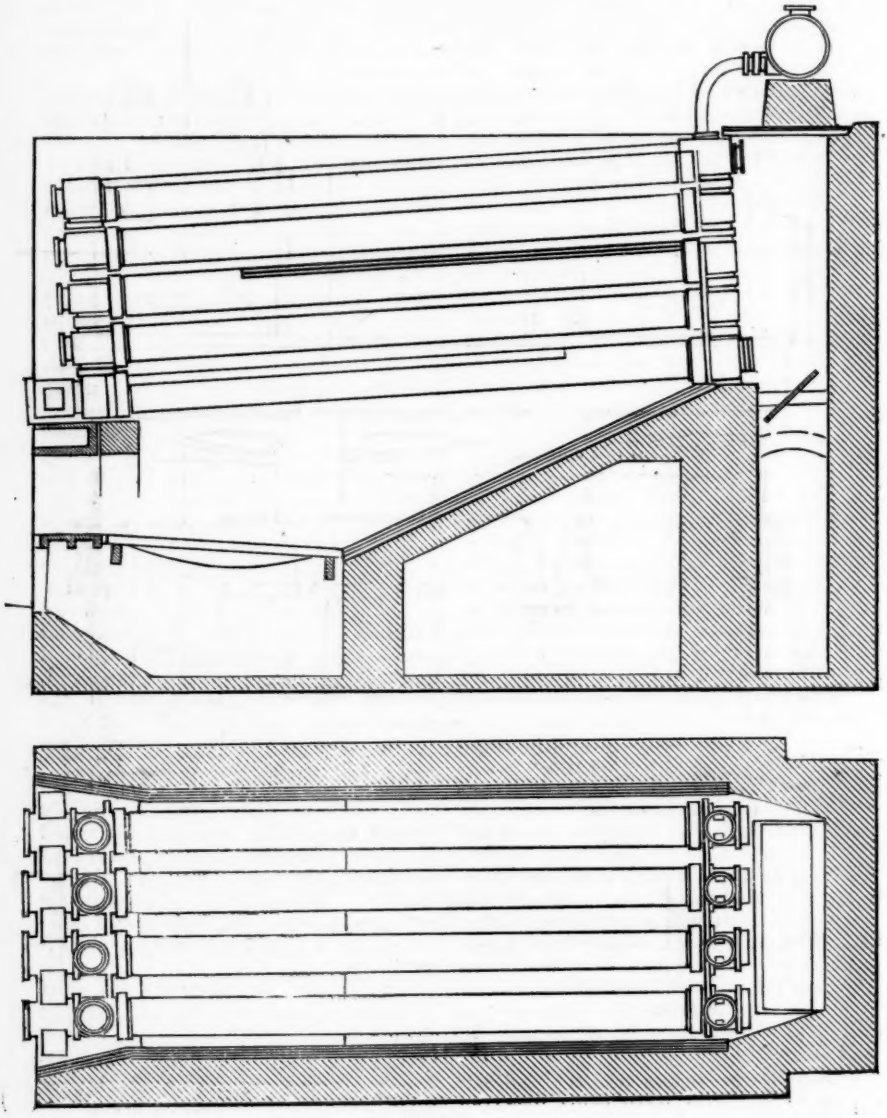


Fig. A.

pair of internal bolts at each end of each section, these bolts which are of rectangular sections, lying close to the sides of the caps, and being furnished at their

lower ends with ⊥ heads, which take hold of lugs cast inside the lowest caps, as shown in Figure 1 of the detail views. * * * * * On the outside of the caps are cast square flanges and ribs for holding fire bricks or tiles for

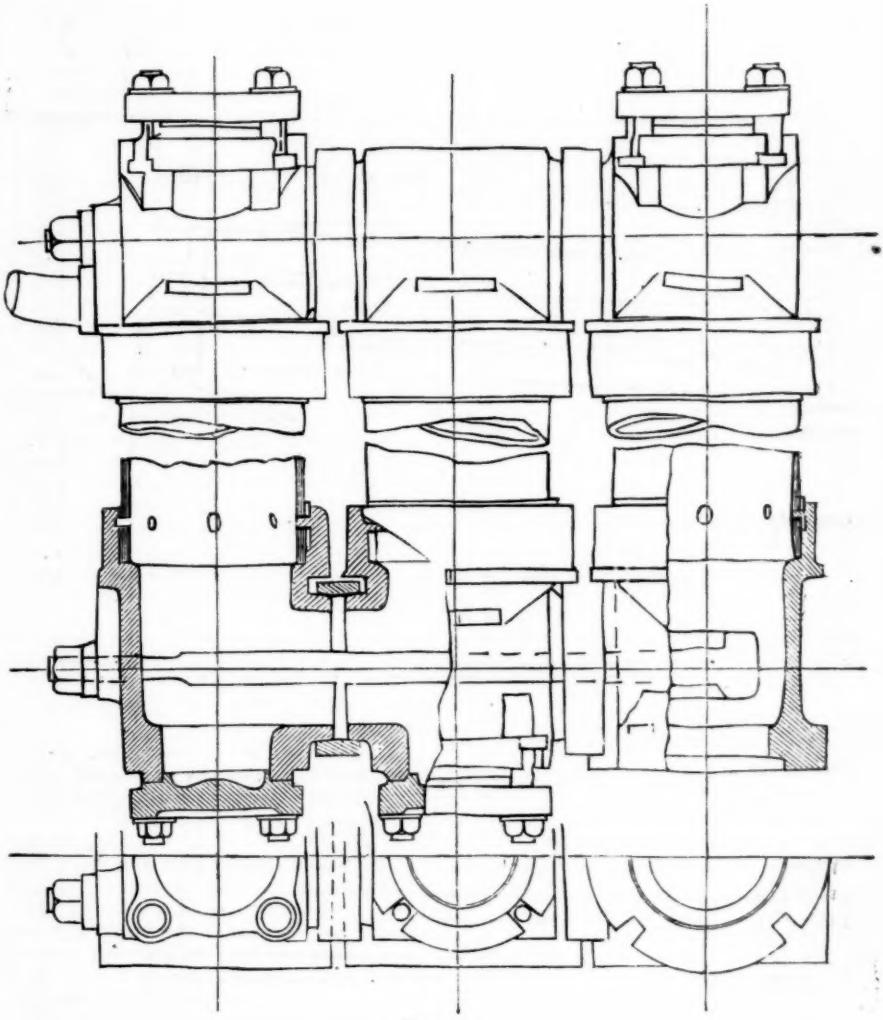


FIG. 1.

closing up the spaces between the sections."

"The arrangement of the setting of the boiler will be readily understood from the general views (Fig. A), from which it will be seen that the steam is led off through curved pipes from the higher end of the section to a steam drum."

In the boiler which was used during the fair, the inclined tubes were connected at one end only with wrought iron vertical tubes by screwed joints. The

openings between the tubes are in some places closed by iron plates laid upon them, causing the products of combustion to take the tortuous course indicated by the arrows.

The opening from the furnace to the flue is closed, except at the top, by a brick wall, thus preventing any of the hot gas passing directly into the flue without going between the tubes.

The opening into the chamber containing the nests of pipes is closed at the front end by cast iron plates, each plate being long enough to reach from top to bottom, and about 6″ wide. These plates are locked together and held in place by suitably arranged lugs. By taking down these plates, each of which could be easily handled by one man, the whole exterior surface of the tubes could be inspected and cleaned and by removing the caps to the heads, each of which was held in place by one bolt; the whole interior surface of the tube could be cleaned. The feed water is introduced into the lowest horizontal section at the front, and may find its way into any of the tubes in this horizontal section, but can only reach the upper tubes through the back end.

The following are the principal dimensions of each of the four sections of boilers on exhibition, each of which could have been used separately or in conjunction with the others by suitably arranged valves :

Grate surface, 27 □′
Heating do. 593 □′ ratio to grate, 22 : 1
Superheating surface, 294 □′ " " 10.9 : 1
Cross area of passage for products of combustion between the grate bars, 10 □′ ratio to grate, 1 : 2.7
1st connection 1.9 □′ " " 1 : 14.1
2d do. 6.7 □′ " " 1 : 4
3d do. 3. □′ " " 1 : 9
into flue (original) 3 □′ " " 1 : 9
into flue (reduced) 1.25 □ " " 1 : 21.6
steam room, 128 cubic ft. ratio to grate, 4.7 : 1
water room, 74 cubic ft. ratio to grate, 2.7 : 1
lbs. of water in boiler at two gauges, 4200
mean area of smoke stack, 4.36 □′ ratio to grate 1 : 62
height of smoke stack above grate, 60′
surface of boiler exposed to radiant heat of fuel, 45 □′
mean distance from top of fire, 2.′6″
distance traveled by product of combustion while in contact with tubes, 34′
diameter and thickness of tubes, 9—$\frac{5}{16}$″
length of tubes, 12′
diameter and thickness of steam drum, 12″—1″
length of steam drum, 6′

The arrangement of these sections in reference to the flue and chimney is shown in Fig. 6.

One section No. 3 was selected for trial.

It was decided by the committee to test the capacity and economy of the boiler under two steam pressures in order to determine whether there was any difference in the working. These tests took place on the 17th and 18th of December, 1874, the first being under a pressure of 75 lbs. by the gauge, and continuing from 7.30 p. m. on the 17th until 5.30 a. m. on the 18th ; the second being under a pressure of 135 lbs. by the gauge, and continuing from then until 4.30 p. m. on the 18th.

Before commencing the first experiment steam was got up in the boiler to 75 lbs. with wood and coal, which was then drawn from the furnace and carried from the room.

The grate and ash-pit were then swept clean, and 46 lbs. of dry pine wood laid in the furnace, kindled and supplied with coal as fast as it could be ignited.

At the time the wood was kindled in the grate the experiment was held to commence.

While the fires were drawn from the furnace the height of the water in the glass gauge was marked, and was maintained as nearly as possible at this height during both experiments, and was brought there after the fires were drawn at the end of each.

The coal was weighed out in lots of 300 lbs. each, and as fast as required, a fresh lot being laid upon the floor as soon as the last one was all upon the fire. The lbs. of coal entered upon the log are those recorded by the man at the scales,

thus at 9.30 p. m, when there is marked 1800 lbs. of coal, 1500 lbs. of this may have been on the fire and 300 lbs. on the floor.

It was intended to fire often and as regularly as possible. As much coal as the fire required was fed on about every fifteen minutes. The draft was not good and the fires were worked a great deal with the slice-bar, and a great deal of fine coal forced through the grates into the ash-pit by the efforts of the fireman to force the fires. The kind of grate used, the "Tupper bar," dividing the grate into small openings, $\frac{1}{2}'' \times 1\frac{1}{2}''$, with an intermediate rib $\frac{1}{2}''$ thick, did not allow the fires to be pricked up from below. It is believed that if this could have been done a considerable more active combustion could have been maintained.

The fires were thoroughly cleaned at 3.30 a. m. on the 18th, after having been in use nine hours. The total refuse for the first ten hours was 373 lbs., or about 15 per cent. of the coal probably consumed during that period.

The fires were maintained at a uniform thickness of from 7 to 9 inches.

The coal was "Lackawanna" of apparently good quality and was in uniform lumps of nearly 3″ greatest dimension.

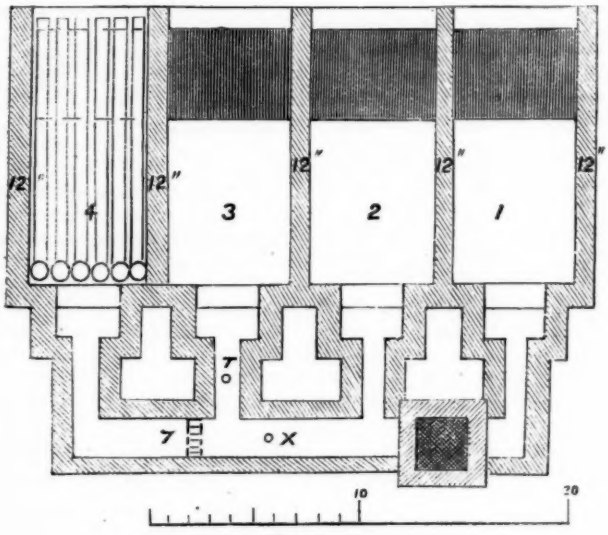


FIG. 6.

It was fed to the fire without being picked, directly as it comes from the coal yard.

The ashes and clinker, and all the material remaining on the grate at the end of the experiment, were weighed while dry and deducted from the weight of coal fed in. The balance being charged as "*combustible.*"

The feed water was fed into the boiler by an injector from a wooden tank on one side of the fire-room. This tank was 14′ $0\frac{1}{2}''$ long by 5′ $10\frac{1}{4}''$ wide, and 7 ft. deep.

A brass rod divided into inches and tenths, was arranged to slide vertically in a socket screwed fast to the side of the tank. This rod was provided at its lower end with a hook, which formed a little dimple in the surface of the water whenever the point was a little above or below. By moving the rod slowly up and down, and by watching the appearance, disappearance and reappearance of this little dimple, the point of the hook could be adjusted as accurately to the surface as the review on the socket would read — $\frac{1}{100}$ of an inch.

The weight of water corresponding to one inch of depth of the tank was 317

lbs. nearly, so that the weight of water which had been fed into the tank was able to be measured within $3\frac{1}{100}$ lbs. at any instant.

The gauge was adjusted to the surface of the water, clamped and read every half hour, and at the expiration of the half hour was read again in its original position before being readjusted to the lower level.

The tank was so large as only to need to be replenished once during the whole time.

It was intended to keep a steady feed on the boiler, but the injector would not feed so slowly and had to be shut off about $\frac{3}{4}$ of the time. The tank was mounted on blocks two feet above the ground, so that its whole surface was visible.

It was practically tight, the leakage not exceeding 50 lbs. during the whole trial.

In place of condensing all the steam that was formed in the boiler in a surface condenser, and measuring the weight of water so condensed together with the weight of the condensing water and the corresponding temperatures, as was done by the Committee in 1871,* the following plan was adopted. It is believed this method was first suggested by J. D. Van Buren, Jr., C. E., late Engineer Corps, U. S. N., Assistant Engineering Department of Docks, New York: A small portion of the steam was drawn from the steam drum in the neighborhood of the safety valve, and conducted through 25 ft. of $1\frac{1}{2}''$ pipe to a worm on a tank of water. This pipe was carefully wrapped with felt $1\frac{1}{2}''$ in. thick, and was provided with a valve at the end near the steam drum, by which the amount of steam flowing to the worm was regulated. There was also a valve on the outlet from the worm. The worm consisted of 32 pieces of $1\frac{1}{2}$ pipe each 30″ long, and connected together to form a rectangular spiral, the whole coil being immersed in the water. A short pipe was led from the end of the worm through the side of the tank, and delivered into a barrel placed on scales close by. Condensing water was led into the tank at the top from the croton main through a pipe provided with a valve to regulate the flow.

This water discharged itself through an orifice in the bottom of the tank into a waste pipe leading to the sewer. The tank was the same that had been used for the rotary engine test at the Fair, and for the test on the circulating pumps on the U. S. S. "Tennessee," by Chief Engineer Shock, U. S. N. The amount of water which would be discharged by this orifice at various heads had been found by previous experiments on the "Tennessee." The following is an extract from the report on that occasion:*

"The following are the mean results of 49 experiments with a head greater than three feet:

Head of water above plate, in inches.	Cubic feet discharged by each orifice per sec'd.
72.154	.1059
52.660	.0900
41.050	.0796

"Fifty-four experiments on less heads than these gave results varying among themselves from zero to twenty-five per cent., and are therefore rejected.

"The amount of water discharged from the same orifice at different heads should vary, if there were no causes of disturbance, as the square root of the heads.

"The following comparison of the amount discharged actually and computed for the last two cases, by a comparison of the square root of the heads with the amount delivered in the first case, shows that the discharge does vary as the square root of the head, as the differences are within the errors of observation:

Head in inches.	Discharge by Experiment.	By Comparison.
72.154	.1059	———
52.660	.0900	.09019
41.050	.0796	.07964

"The co-efficient of contraction being the ratio of volume of water actually discharged to that represented by the area of the orifice multiplied by the theoretical velocity, is"

$$C=.7766.$$

* See Rep. Com. of Boiler Test. Am. Inst. Trans., 1871.

* Reports of trial of circulating pumps on U. S. S. "Tennessee," 1874.

NUMBER OF CUBIC FEET WHICH WILL BE DISCHARGED IN ONE HOUR FROM A SINGLE ORIFICE AT VARIOUS HEADS, COMPUTED FROM EXPERIMENT BY A COMPARISON OF THE SQUARE ROOT OF THE HEADS.

Head in inches.	Discharge.	Head in inches.	Discharge.
72	380.8	52	328.7
71	378.2	51	320.6
70	375.5	50	317.4
69	372.8	49	314.2
68	370.1	48	311.0
67	367.4	47	307.8
66	364.6	46	304.5
65	361.9	45	301.1
64	359.1	44	297.7
63	356.2	43	294.3
62	353.5	42	290.9
61	350.6	41	287.4
60	347.7	40	284.0
59	344.8	39	280.3
58	341.8	38	276.7
57	338.8	37	273.1
56	335.9	36	269.3
55	333.0	35	265.6
54	329.9	34	261.7
53	326.8	33	257.9
52	323.7	32	254.5

The tank was of boiler iron 48″ diameter and 72″ deep, and $\frac{3}{8}$ thick.

Soon after starting fires in the boiler the steam was turned into the worm and the croton water into the tank.

The valve in the croton water pipe was adjusted so as to supply as much water as would flow through the orifice under a head of 56½ inches, and was not changed until the experiment was concluded on the following day. It was intended to adjust it so that the head of water would be 60″, but the variation of level was so slow when there was nearly an equilibrium established between the inlet and the discharge that after it was supposed there was an equilibrium, that is when there was no visible variation of level and the valve made fast, the surface of the water sank slowly during the next hour from 60″ to 56½″, as recorded in the log. The croton water was drawn from the main in 2d Avenue.

As the orifice in the bottom delivered a uniformly varying quantity proportional to the square root of the head of water in the tank, and as there was a constant area of opening in the croton water supply pipe during the whole experiment, if there was any variation of head in the tank it must have been from a variation of pressure in the croton main.

The pressure in the main undoubtedly does vary at different hours of the day with the consumption of water.

The head of water in the tank indicates that the pressure was greatest from 3 a. m. until 5 a. m., and was least from 8.30 until 9.30 a. m.

The consumption undoubtedly varies in the inverse. The following table shows the variation of pressure as indicated by this experiment at different hours during the day. This variation is only true for the section supplied by the main at *this season*.

Hour.	Pressure.	Hour.	Pressure.
9.30 P.M.	94.1	7.30 A.M.	95.
10.30 "	94.1	8.30 "	83.3
11.30 "	96.7	9.30 "	90
12.30 A.M.	96.7	10.30 "	91 7
1.30 "	98.3	11.30 "	93.3
2.30 "	98.3	12.30 "	93.3
3.30 "	100	1.30 P.M.	93.3
4.30 "	100	2.30 "	93.3
5.30 "	100	3.30 "	93.3
6.30 "	95		

These figures indicate that the consumption commences to increase after 5.30 in the morning and rises rapidly to a maximum at 8.30. From 8.30 it diminishes slowly until 11, after which it remains nearly constant during the day, then slowly falls until 2 a. m., becoming a minimum at from 2 a. m. until 6 a. m.

The weight of water condensed in the worm being known and the temperature of the water of condensation, and also the weight of the condensing water and the temperature of the injection and discharge, the degree of superheating of the steam, if it is superheated, or the amount of water entrained with it, may be computed.

All the steam that was formed in the boiler and was not condensed in the worm was allowed to escape into the atmosphere through the safety valve. As the steam which flowed to the worm was drawn from the steam drum within a few inches of the safety valve, there is no reason to suppose that it was not of the same quality as the steam which

flowed through the valve. It is on the correctness of this assumption that the exactness of this method rests.

The apparatus for condensing the steam may be as small as convenience requires, and will give accurately the quality of the steam.

The total weight of steam evaporated is given by the measurement of the feed water before being pumped into the boiler.

There was a high grade thermometer in a mercury cup in the steam drum. This thermometer did not indicate as high a temperature as that due to the temperature of the steam.

Notwithstanding that the thermometer did not record the exact temperature of the steam, its variations served to show that the steam was *not super-heated.*

The temperature of the gas leaving the boiler was tested by a thermometer in a sand bath in the flue marked T in Fig. 6. Fig. 10 shows a section of the flue at the point when the thermometer was inserted, and the amount of contraction from the original size of the flue.

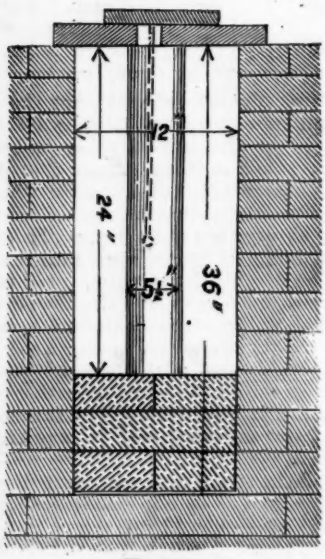


FIG. 10.

The sand bath was a piece of 5½″ iron pipe, plugged at the bottom and filled with sand. The thermometer was lowered into the pot through a hole in the tile covering the flue, which was closed with a block of wood except when the thermometer was being examined.

The temperature of the gas in the main flue was occasionally taken with the same thermometer, without the sand, at the point marked X in Fig. 6. This temperature was always considerably less than that of the connecting flue. It is believed that this difference was due to the cold air which leaked into the flue through the boiler No. 4, in Fig. 6, and mixed with the hot gas from the boiler being tested. It was believed during the experiment that all connection between boiler No. 4 and the main flue had been closed by a brick wall temporarily erected across the flue at y, Fig. 6. It was found, however, after the experiment this brick wall had partly fallen down, exposing an opening of at least one-half a square foot.

The furnace and ash-pit doors of boiler No. 4 were kept closed during the experiment, and as these doors were well fitted it is believed that no appreciable amount of air leaked in through them, but that all the air leaked through *the false front and openings in the brick-work.*

The connection between the other boilers, Nos. 1 and 2, was closed by luting the dampers provided with *fire clay.* The tightness of this joint was tested during the experiment by making a small fire of shavings in the furnaces of these boilers and watching the course of the smoke, which all returned into the fire-room through the furnace door and through the *openings in the iron front.*

The pressure of the gas in the chimney was measured by a Siphon gauge, the leg entering the chimney being a ¼″ iron pipe, continuing through the brick work to the center of the flue, the end being turned *up.* There was also a similar gauge with the end bent *down.* It was expected that the velocity of the air in the flue could have been determined by the difference of height of the column of water in these two gauges. The gauge connecting with the tube *bent down* would have measured the difference of weight of the column of air within and without the chimney, while the gauge connecting with the tube bent up would have indicated a pressure less than this weight by the weight of a column of hot

gas of sufficient to give the experimental velocity to the gas in the chimney. It was found, however, that this difference of height, although perceptible, was too small to be measured by the gauge.

This difference being the height of a column of water equal in weight to a column of hot gas through which a body falling would acquire the velocity of the gas in the chimney, may be determined as follows :

Velocity of gas in chimney from experiment in feet per second	11.25
Weight of a cubic foot of gas at 230°	.05988
Weight of a cubic foot of water at 60°.	62.4
Height due to a velocity of 11.25 feet	1.9625
Weight of a column of gas 1.9625 feet high	·1177
Height of a column of water of same weight	.0226″
Measured height of syphon gauge with end bent up	.161
∴ Measured height of syphon gauge with end bent down (.161 + .0226) =	.1836

A very striking example of the experimental fact that a gauge connected with a tube, having an orifice directed against the current of gas, will not indicate a less pressure than that in the reservoir from which the pressure flows, is cited by chief engineer Isherwood, U.S.N.

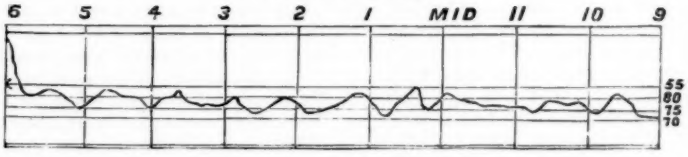
In some experiments being made to determine the necessary size of orifice for a safety-valve on a boiler, in one case a 2″ pipe 4′ long was tapped into a steam drum, both ends being open. A steam gauge was connected with a long ½″ pipe which could be run down through the 2″ pipe until the end was well inside of the steam drum.

While steam was raised in the boiler and rushing out into the atmosphere through the 2″ pipe, the gauge pipe was gradually withdrawn, and the reading of the connecting gauge noted for every position from the time when the end was on the steam drum until the time when it was several inches beyond the end of the escape pipe.

The gauge marked the nearly same pressure—nearly the pressure of the steam in the boiler—40 lbs. in every position. The copies of the logs of the two experiments following will explain themselves. The figures in the column headed "height of water in tank," indicate the readings of the gauge, and the amount of water fed in will be found by subtracting the reading of the gauge at the beginning of the interval from the reading at the end.

The following are diagrams from Edson's Recording Time Gauge, which worked well during the whole experiment, the vertical figure marking the pressures and the horizontal the hours :

1st Experiment.



2d Experiment.

Abstract of Howard Boiler, December 17th and 18th, 1874.

Total Quantities.

	1st.	2d.	Mean.
Duration of experiment hrs.	10.5	11	21.5
Lbs. of coal fed into furnace	—	—	5100
Lbs. of coal and ashes withdrawn	—	—	1158
Lbs. of combustible consumed	—	—	3942
Lbs. of water fed into boiler	17338	21015	37403
Lbs. of water entrained with steam	452	3100	3552
Lbs. of water evaporated	16886	17915	34801
Lbs. of water condensed in worm	3483	5418	—
Number of minutes worm was in use	485	530	—

Pressure.			
Steam in boiler	76.5	138.3	—
Siphon gauge in chimney	.155	.145	.150
Barometer			
Temperature.			
Feed	35°	36°	35¼
Atmosphere	35°	45°	40
Steam (by thermometer in drum)	314°	346.8	—
Gas leaving boiler	332°	324°.2	—
Gas entering chimney	—	234°	—
Water from worm	90°.7	103°.8	—
Injection	37°.5	36°	—
Discharge	59°.5	64°.82	—
Mean Quantities.			
Lbs. of combustible per hour	—	—	183.5
Lbs. of combustible per sq. foot of grate	—	—	6.8
Lbs. of combustible per sq. ft. of heating surface	—	—	0.308
Apparent evaporation per lb. of combustible	9.024	9.915	9.469
Weight of water entrained with steam per lb. of combustible	.226	1.547	—
Effective evaporation per lb. of combustible	8.798	8.368	8.543
Effective evaporation per lb. of combustible from 212°	10.75	10.28	10.53
Per centage of total absorption (useful)	.742	.709	.726
Per centage of water entrained with steam	2.6	15.5	—

DISCUSSION OF RESULTS.

From an inspection of the cuts, together with the description, it will be seen that this boiler belongs to the water tubular type, *i. e.* to that class of boiler having the water within the tubes and the products of combustion on the outside. This class of boiler has given the highest recorded economical performance of any boiler in use, being in one case as high as 90 per cent. of the total heat contained in the coal, given with a rate combustion of 6½ lbs. of combustible to one square foot of grate per hour, and with a proportion of grate surface to heating surface of 32½ to 1, both being nearly the same as during this experiment.*

It has been found experimentally that the efficiency of combustion, *i. e.* the proportion of the total heat in the fuel which is developed by its combustion does not sensibly vary within the limits of practice of steam boilers either from a variation of the rate of combustion or of the thickness of the bed of fuel on the grate.

* Report of Board on Horizontal and Tubular Boilers, Phila., 1868.

*"It is a matter of popular belief that, owing to insufficient air admission, carbonic oxyde is formed in the furnaces of steam boilers, in which case a loss of heat would be sustained equal to that which would be developed by its further oxydation to carbonic acid." Whether such is the fact or not can only be determined by a chemical analysis of the product of combustion. Many such analyses have been made with widely varying thickness of bed of combustible and greatly different rates of combustion, but they all agree in indicating that the proportion of carbonic oxyde is very small, not exceeding about six per cent. in the worst cases, and that it is not sensibly affected by the thickness of the bed of fuel, at least not within the limits of practice. Also that the air admitted through the grate bars is about double that which is chemically necessary for perfect combustion, the free oxygen composing about 10 per cent. of the products of combustion. These analyses also show that the combustion more nearly approaches perfection in the higher than in the lower rates. In the same furnace the higher rate is attended with a less proportion of carbonic oxyde, of free oxygen, of combustible gases in the products of combustion, and with a higher furnace temperature than in the lower rate. The higher economic rates obtained in steam boilers with the lower rates of combustion must be ascribed, not to the development of more heat from the more complete oxydation of the combustible, but to the absorption of more heat from the water heating surfaces due to the less quantity of heat thrown upon them in a given time; the proportion of heating to grate surface, habitually given, not being sufficient to reduce, even with the lowest rate of combustion practicable, the temperature of the products of combustion to that of the water heated. With the heating surface increased in the same ratio as the rate of combustion, and arranged in such a manner as to have equal heat absorbing efficiency, the higher rates would probably be attended by an increased economic evaporation, though not to any considerable degree.†

* Experimental Researches in Steam Engineering. B. F. Isherwood.

† Ex. Res. in Steam Engineering, Vol. II. p. LXIII.

THE DIFFERENCE OF THERMAL ENERGY TRANSMITTED TO THE EARTH BY RADIATION FROM DIFFERENT PARTS OF THE SOLAR SURFACE.

By Capt. J. ERICSSON.

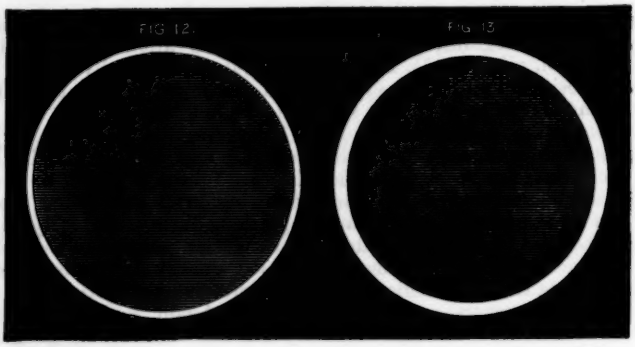
From "Nature."

The observations relating to the temperature of the polar regions, referred to in the article (vol. xii., p. 517), at first led to the supposition that the rays projected from the north pole of the sun transmit a perceptibly greater energy to the actinometers than the rays from the opposite pole. Subsequent observations having positively established the fact that the polar and equatorial zones transmit equal intensities, it became evident that some other cause than difference of temperature within the polar regions influenced the actinometers. The only valid reason that could be assigned in explanation of the anomaly being the considerable angle subtended, and the consequent difference of zenith distance of the opposite poles of the sun, my table of maximum solar intensity for given zenith distances (prepared from data collected during a series of years) was consulted, in order to ascertain the influence of zenith distance. The observations indicating a higher temperature at the north pole, it should be mentioned, had been made while the sun's zenith distance ranged beeween 32° and 33° at noon. Now the table referred to shows that there is a difference of radiant intensity of $63°.63 - 63°.40 = 0°.23$ F. between the stated zenith distances. The mean angle subtended by the sun being fully thirty-two minutes, it will thus be seen that owing to the absorptive power of the terrestrial atmosphere, the radiant intensities transmitted from the opposite poles of the luminary differ considerably. The magnitude of this difference, adequate to explain the discrepancy under consideration, need not excite surprise if we consider that thirty-two minutes of zenith distance involves an additional depth of more than half a mile of atmosphere to be penetrated by the rays projected towards the actinometer from the *south* pole of the sun. The foregoing facts show the necessity of taking the difference of zenith distance between the opposite poles into account in making exact observations of the sun's polar temperature, especially at the lower altitudes where the secant of the zenith distance increases rapidly.

Regarding the calorific energy of the radiation emanatiug from the border of the sun, I deem it proper to present the following brief statement. Several observations during the early part of the investigation pointed to the fact that increased energy is transmitted to the actinometers by radiation from the sun's border. Again, considerable irregularity was observed in the progressive diminution of the force of radiation towards the circumference of the solar disc. It was shown in the preceding article (vol. xii. p. 520) that the radiation from the border zone, $1' 42''$ wide, occupying one-fifth of the area of the solar disc, transmits 0.638 of the intensity transmitted from an equal area at the centre of the disc. Of course it will be supposed that the rate of the diminution of intensity within the zone thus ascertained is much greater near the border of the photosphere than at the middle of the zone. Such, however, is by no means the case, notwithstanding the assumption of physicists that the heat transmitted by radiation from the border is very feeble. In order to test the truth of the indications referred to, showing considerable radiant energy at the border of the photosphere, a very careful investigation was made, Sept. 9, 1875, by means of screens excluding the ray from the solar disc, as shown in Figs. 12 and 13. The diameter of the screen represented in Fig. 12 being 154.06 millimetres, covered nine-tenths of the area of the disc; while the screen shown in Fig. 13, being 145.25 millimetres, covering four-fifths of the disc. It will be well to mention that the dimensions of the screens referred to correspond with the angle subtended by the sun when the earth is in aphelion. Ac-

cordingly the distance between actinometers and the screens was adjusted previous to the observation, viz., shortened, in order to compensate for the increase of the angle subtended by the sun. Agreeable to the stated dimensions of the screens, it will be found that the zone represented in Fig. 13 is 1′ 42″, while the zone in Fig. 12 is 49″.6. The mean width of the latter is consequently situated only 24″.3 from the border of the photosphere.

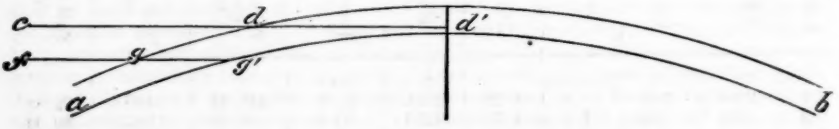
The following table shows the intensities transmitted to the actinometers from the zones represented in Figs. 12 and 13:



Time.	Zone, Fig. 13. Cent.	Zone, Fig. 12. Cent.	Rate of difference.
4′	2°.011	1°.333	$\frac{1.333}{2\ 011}=0.662$
5′	2°.248	1°.471	$\frac{1.471}{2\ 248}=0.654$
6′	2°.425	1°.538	$\frac{1.583}{2.425}=0.652$
7′	2°.485	1°.666	$\frac{1.666}{2.485}=0.670$
			Mean=0.660

The rate of difference inserted in the last column, it will be noticed, is not quite so consistent as in the table contained in the previous article recording the observations made Aug. 25. The discrepancy is, however, not material, the difference between the lowest and the mean rate being 0.008. It will be seen on inspecting the registered intensities, that the border zone represented in Fig. 12, whose area is only one-half of the area of the zone in Fig. 13, transmits 0.660 of the intensity of the latter.

IG. 14.



This at first sight indicates an extremely disproportionate transmission of heat from the narrow border zone; but it should be considered that the inflected radiation imparts relatively more heat to the actinometer exposed to the radiation from the narrow zone than from the wide zone. It will be readily understood that since the inflection of the calorific rays is 14″.7 (see preceding article), the first-mentioned actinometer receives radiant heat from 14′.7+49′.6= 64″.3; while the actinometer exposed to the radiation from the wide zone receives heat from 1′ 42″+ 14″.7 = 116″.7. Consequently, the radiant heat emanating from the narrow zone will be $\frac{64''.3}{116''.7}=0.551$ of that transmitted from the wide zone, hence somewhat more

than one-half. Our investigation therefore proves that the radiant heat transmitted from the narrow border zone represented in Fig. 12 is 0.660 — 0.551 = 0.109 more intense than that transmitted from the zone represented in Fig. 13, although the mean distance of the latter is twice as far from the border of the photosphere as the mean distance of the former. The singular fact thus revealed can only be accounted for by supposing that internal radiation is not incompatible with the constitution of the photosphere, and by adopting Lockyer's views expressed in the Senate House of Cambridge, 1871, that "the photosphere must be a something suspended in the solar atmosphere." Let *a b*, Fig. 14, represent a section of the "suspended" photosphere, and *d c*, *g f*, rays projected towards the earth. Agreeable to the conditions mentioned, and in view of the fact that the force of radiation from incandescent gases presenting equal areas, varies nearly as their depth, we are warranted in concluding that since the depth *d d'* is greater than *g g'*, the radiant heat transmitted from the photosphere by the ray *d c* will be greater than that transmitted by the ray *g f*. It shoulld be observed that the energy transmitted towards the earth by *d c* suffers a greater diminution than the energy transmitted by *g f* in consequence of the greater depth of the solar atmosphere penetrated. Hence the augmented energy established by our investigation, does not show the full amount of the increase of radiant heat transmitted from the border of the sun.

THE EIGHTY-ONE TON GUN.

From "Engineering."

DURING the last and present months further experiments have been made at the proof butts of Woolwich Arsenal with the 81-ton gun, in the view of testing its capacity with its present calibre of 14½ in., before the bore is enlarged.

THE 81-TON GUN: PARTICULARS OF EXPERIMENTAL FIRING.

Number of Round.	Weight of Projectile.	Weight of Charge.	Size of Powder Grains.	Density of Powder.	Muzzle Velocity.	Pressure per Square Inch of Gun.	Foot-tons of Energy per Inch of Shot's Circumference.	Total Energy in Foot-tons.	Foot-tons per Pound of Powder.
	lb.	lb.	in. cubes		ft.	tons.			
1	1260	220	1.5	1.76	1525	25.8	445.94	20,313	92.33
2	1260	220	1.7	1.76	1420	20.6	386.66	17,612	80.05
3	1260	230	1.7	1.76	1454	20.2	405.39	18,465	80.28
4	1260	240	1.7	1.76	1470	21.0	414.37	18,874	78.64
5	1260	220	1.5	1.78	1505	24.1 to 26.3	434.33	19,784	89.93
6	1260	220	1.7	1.78	1502	23.0	432.59	19,705	89.57
7	1260	220	2	1.78	1481	21.7	420.60	19,157	87.08
8	1260	230	1.7	1.78	1543	24.9	456.54	20,796	90.41
9	1260	230	2	1.78	1498	23.4	430.30	19,598	85.22
10	1260	240	2	1.78	1513	23.0	438.95	19,995	83.31
11	1450	220	1.5	..	1440	28.0	437.57	20,842	94.74
12	1450	220	1.7	..	1414	25.0	442.22	20,097	91.35
13	1450	220	2	..	1366	24.4	411.75	18,756	85.25
14	1260	250	2	..	1522	24.8	444.78	20,259	81 04

In the first series of trials the powder charges varied from 170 lb. to 240 lb., and the weight of projectiles from 1258 lb. to 1260 lb. A maximum muzzle velocity of 1550 ft. was then recorded, with a total striking energy of 20,984 foot-tons, and a pressure on the powder chamber of 29.6 tons per inch, a strain far beyond the assigned limits. The table above summarises the practice made with the gun since the trials above made.

From these figures it will be seen that the ranges of powder charges varied from 220 lb. to 250 lb., and the weight of projectiles from 1260 lb. to 1450 lb., while the pressures recorded increased from 20.2 tons to 28 tons per square inch, the latter being given by the smallest size of powder employed, namely, 1 in. cubes. Of the series, round No. 8 shows the most favorable result, as with a 230 lb. charge of medium-sized powder, and a pressure of 24.9 tons, a muzzle velocity of 1543 ft. was obtained, and a total energy of 20,796 foot-tons, equivalent to a duty per pound of powder burnt of 90.41 tons. Comparatively small increase in striking energy was obtained by using the heavier projectile, while the pressure on the gun increased considerably. The maximum strains were produced by the smallest cubes of powder, and the largest size, whilst not throwing so much work on the gun, put less into the projectile. The powder in 1.7 in. cubes, therefore, appears in all respects best suited for the work. The advantage lay also with the use of the shot of 1260 lb., instead of the heavier projectiles, of which three rounds were fired.

The total amount of energy per pound of powder charge in the 81-ton gun, as compared with that of the lighter calibres is of interest. Thus if we take the Woolwich and Krupp 10 in. guns, which Mr. Longdon was the other day contrasting with each other, greatly to the disadvantage of the former, we find that the figures are as follows:

(*See Table on following column.*)

From the performance of the Krupp guns it would appear as though the work done by the powder diminished with increase in calibre, though of course so partial a comparison forbids any actual conclusion.

	Powder Charge	Total Energy.	Foot-tons per Pound of Powder.
	lb.	foot-tons.	
81-ton gun.....	230	20,796	90.41
10-in. Woolwich gun	70	5,160	73.70
9-in. Krupp.....	84	6,610	66.70
10-in. Krupp.....	100	6,270	62.70

The 81-ton gun is, we believe, to be immediately enlarged in calibre from 14½ in. to 16 in., when a fresh and still more interesting series of trials will be commenced. So far as experience has gone, we may fairly congratulate ourselves on possessing the largest useful piece of ordnance in the world. We say useful, because no trials have been ventured upon with the monster gun made some years since by Herr Krupp. We believe, however, that some pieces of ordnance as large, if not larger, than our 81-ton gun, are now in progress in Essen, and when completed they will no doubt be as perfect representatives of steel ordnance as the 81-ton gun is of the Woolwich system. We shall look forward with interest to the trials of these large Krupp guns, for not only will they test the reliability of steel ordnance to the utmost, but ample experience of the efficiency in the largest calibres, of the Broadwell system of breechloading as employed by Krupp will also be ascertained.

THERE are eight completed Bessemer steel establishments in the United States, and every one of them, says the *Bulletin Iron and Steel Association*, is running to its full capacity, and is full of orders. Two of these are at Chicago, one at Joliet, and one at Newburg, near Cleveland. The new Edgar Thomson Bessemer works near Pittsburg, a magnificent plant, will soon be in operation, and the Bessemer plant of the Lackawanna Iron and Coal Company at Scranton will also be completed soon. At St. Louis the Vulcan Ironworks are at work on a Bessemer plant, to be ready this year, making the eleventh in the country. It will be observed that, if we include Pittsburg, the west will have six of the eleven.

THE ARCH QUESTION AGAIN.

By CHAS. A. SMITH, C. E.

Written for Van Nostrand's Magazine.

In an article published in this Magazine, p. 514, vol. 13, Dec., 1875, Mr. Wm. Cain, A.M., C. E., makes some statements calculated to convey wrong impressions, as follows:

He says, "As to the usual statement that a line of pressures cannot pass outside of the middle third of the arch ring without the arch tumbling (a fallacy of Rankine and other authors) we have only to remark that experiment undoubtedly and finally disproves it." The above quotation only leads me to infer that Mr. Cain is ignorant of the statements made by Rankine, whatever he may have taken from other authors. Rankine says expressly (vide "Civil Engineering," p. 220) "The properties which the line of resistance and line of pressures must have in order that the conditions of stability may be fulfilled, are the following:

"*To insure* stability of position, *the line of resistance must not deviate from the centre of figure of any joint more than a certain fraction of the diameter of the joint measured in the direction of the deviation.*"

I do not suppose Mr. Cain is inclined to dispute the above condition, and the only question left is the amount of the ratio of the deviation admissible. Rankine calls the ratio of deviation "q," and says on p. 397: "The following are average values of 'q' deduced from the dimensions of actual retaining walls. According to the practice of British Engineers 'q' = 0.375 nearly."

That is, the line of resistance must not pierce any bed joint nearer the edge than one-eighth of the diameter of the joint. This is a limit of deviation that even Mr. Cain would hardly wish to pass.

Rankine, however, says in regard to flying buttresses (p. 396), and arches (p. 416): "It is advisable to limit 'q' so that there shall be no tension at any part of the joint which for rectangular joints gives 'q' = $\frac{1}{6}$." This is the value Mr. Cain thinks so fallacious, but of which Rankine says (p. 417): "It is true that arches have stood, and still stand, in which the centres of resistance of the joints fall beyond the middle third of the depth of the arch ring, but the stability of such arches is either now precarious or must have been precarious while the mortar was fresh."

In order to fully impress Mr. Cain with the importance of this last quotation, it will be necessary to remind him that engineers usually require for all classes of work a certain margin or factor of safety, and that limiting the curve of pressures to the middle third of the arch ring is identical with employing a factor of safety of 3 in the overturning moment, which most engineers think is small enough for a structure involving the safety of a railway train. A blockwork structure will not open the joints, until the pressure line passes through the edge of the joint, but the edge through which the pressure passes will usually "spawl off" and cause failure, from the material giving way to the compressive stress (which is theoretically infinite, when the line of pressure touches the edge).

The work of Rankine, as a teacher, is to place before the engineer the various cases which may occur, and the working engineer alone can decide which cases his problems come under. The question of load on rafters has been taken up too many times for me to enter upon it here, and I will let it pass with the remark that there is more in Rankine's Civil Engineering than some men find in it.

Mr. Cain casts a slur at the profession when he says "The engineer, strange to say, is not so fond of experimenting, but prefers to *assume* and compute the deduction." I must as a member of the profession say that most engineers of my acquaintance prefer experiments, and what is far better than experiments, viz., successful practice, to any computed "deductions," and certainly no one kind of structure has so many examples of successful practice as the "blockwork arch." Telford erected over one thousand stone arches during his life, and any one needing a precedent can cer-

tainly find one for any kind of "block-work arch" in which he need be troubled with only a very limited amount of calculation. Every completed structure is in itself an experiment and certainly the first question asked by the true engineer for every problem new to him is not "how can I compute this case?" but "how has it been solved?" and after that has been answered "how can the former solutions be improved, and what better one can be given?"

LAND DRAINAGE.

From "Engineering."

For some time past the unusual rainfall has resulted in floods more or less severe, which have been the subject of much general anxiety and local damage. On the Continent as well as in this country, the rainfall during the present year has been peculiarly disastrous; it is true that, periodically, we are liable to an excess of rainfall, and consequently partial inundation of the low-lying districts of the country. But recently the floods which have been experienced have had extraordinary results in the destruction of life and property, and this circumstance suggests many points of interest in regard to land drainage, water supply, the pollution of rivers, and cognate subjects. Although the matter is one of national importance, its details involve to a large extent questions of local inquiry, and it is to these we shall briefly draw attention.

It must be expected that an extraordinary rainfall, in any country, must give rise to floods in low-lying districts, if we only consider the natural obstructions that exist in the course of most rivers that run into the German Ocean. Such natural obstructions consist in bends of the river beds, upheavals of the bottom, weeds, stumps of trees, &c. But beside these, are artificial obstructions caused by the introduction of refuse of all kinds, but especially in mining and agricultural districts. In our mining districts the quantity of refuse thrown from metaliferous and coal mines is enormous, and such causes have been already noticed in our columns when we criticised the reports of the Royal Commission on the Pollution of Rivers. In regard to agricultural causes it is simply necessary to state that whenever a flood occurs, and this generally happens in autumn or spring, when the land has been newly ploughed, a very large proportiou of the surface soil is washed into the adjacent stream, where it gradually settles, lessening the depth, and consequently flooding land lower down on the banks of the river. Last week the nothern piers of Vauxhall Bridge were thus coated with a covering of upwards of a foot deep of soil brought down from the upper portion of the Thames during one tide, and this minor instance is but a slight indication of the enormous deposit cast into our rivers through the washing of the surface soil from adjacent fields.

During the present week we find that at Hampton, Kingston, Richmond, and adjacent places, the Thames has been swollen to an extent unknown for years past. At the intakes of the Metropolitan Water Companies the water was consequently very turbid; in fact it was opaque if viewed to the depth of one inch, according to our own observation. The water, before being drawn into the Thames Companies' reservoirs, was loaded consequently with soil, manure, sewage, and every imaginable abomination that newly ploughed and manured fields, and towns could supply. The extent of pollution caused by the fields may perhaps be little known by some of our readers, but one instance may suffice to show how floods may cause such pollution. Three years ago, for example, a farmer manured heavily a ten-acre field not far from Leeds, on the banks of the Aire. A heavy flood came, and the whole of the manure was swept off on to an adjacent field, which produced well in the following season, while the field originally manured was nearly barren. Now, precisely the same circumstance has been going on, say, during the last few weeks on the banks of all our rivers running eastwards. Most of these, and

their tributaries, are sources of water supply. What a sarcasm does not this fact convey on the action of local authorities, and the advance of engineering science!

The question arises as to whether such results of flood may either be prevented or alleviated, and the latter we consider might be largely accomplished. In countries where floods are perennially expected, provisions are made to obviate ordinary consequences, as in Holland, Egypt, India, and some portions of the United States. Dams and other means are adopted, and even in our own country, the Lincolnshire fens, parts of Bedford and Cambridgeshire, &c, are similarly protected. But in our Midland Counties things are left to their fate. For the last thirty years we have noticed in traveling northwards from London, that about 15 miles from town floods have constantly occurred during autumn and winter, and yet scarcely any attempt of a systematic kind has been made to cure so serious an evil. The farmer has left the flood to wash his seed and manure into the river, and the town authority up to the Registrar-General, has rejoiced to find that the flood has cleansed sewers and reduced the rate of mortality. The first, like the Turk, has submitted to fate with resignation, while the other has rejoiced on the principle that partial evil generally results in general good. And so we have been content to suffer evils rather than seek a remedy,

A very little consideration would show that if land were properly drained, the danger of floods would be materially lessened in the majority of cases. A badly sewered town must constantly be flooded, of which some hundreds of instances have been reported during the last fortnight. But a place like the metropolis, with adequate sewerage, cannot be flooded. Just so in respect to land. If a ready means be provided for the removal of surface water, not only is the chance of flood diminished, but the surface soil and the newly laid manure and seed are kept in their place, Thus several evils are in whole or in part remedied by efficient drainage and improvements, and to this we must therefore in future look for means to lessen the evil results of excessive rainfall.

But a more refined point of science is involved in the question of rainfall. It has long been established that in the same locality, at different altitudes, and at the same moment of time, more rain falls on the ground than is produced at a certain height above it; even a high house shows a less rainfall on its roof than at the basement. This is easily explained. Each drop of rain as it falls accumulates moisture, and consequently increases in quantity. In damp, marshy, and undrained districts, the supernatant atmosphere is loaded with suspended aqueous vapor, consequently the rainfall in such districts generally exceeds that of a similar land and level when well drained. In other words, a well-drained land will, all circumstances being equal, have a less rainfall than one that is badly drained. Hence efficient drainage may from meteorological causes tend to diminish floods. Equally, a land destitute of trees has less rainfall than forest land. Hence it is actually in our power to control natural phenomena to a very large extent with respect to great rainfall and consequent floods.

Passing from scientific to practical questions there is one remedy that has been greatly neglected, and which affords a ready means of largely controlling the effects of a flood—we refer to the proper management of locks and weirs.

Most of our English rivers, above the tidal stream, have been converted into canals, and are also used to provide motive power for mills. Both of these modes of utilizing the stream involves the necessity of keeping a "head" of water. Self-interest and neglect tend in numerous cases to keep up this "head" preceding and during floods, to an unnecessary extent. When the evil has occurred the water is lowered by opening the sluice, but owing to a want of impetus or motion in the water, already at rest, the new flood sweeps over it as if it were a solid mass, and, consequently, the late opening of the sluice becomes practically useless. Numerous instances of this kind have recently come under our notice, in which the lower parts of towns have been unnecessarily flooded with a comparatively small rainfall, while, with a greater, the evil was avoided by a timely attention to the precautions we have alluded to.

Of course the erection of dams and

similar contrivances must be attended with great expense, but even this would be repaid if we calculate the immense loss of property compared with the annual charge of interest on loans necessary for such precautions. It is only a year or two back that in the metropolis itself damage was done to the extent of several thousands of pounds in a few hours that might have easily and cheaply been prevented, and it was amusing if not edifying to have noticed the enormous amount of clay used alike by the Metropolitan Board of Works on the Thames Embankments, and by the poor laundry woman on the Lambeth and Southwark banks, to protect property from the sudden flood of the Thames within even City limits. Such matters should not occur in our present state of engineering science.

We have thus briefly drawn attention to some important questions that naturally present themselves for consideration, owing to the extensive floods that have prevailed for the last fortnight. It is evident that we have abundant means within our reach to largely diminish the evil and losses which sudden and excessive rainfall has brought down. The loss of property and life which has occurred is serious enough, but when the evil that may arise to our water supply is also properly estimated, there is surely sufficient stimulus to set about some active measure throughout the country, to remedy or prevent a recurrence of such misfortunes, especially as so many other important sanitary matters are involved in the question. We are glad to find that the Local Government Board has just issued a commission to make preliminary inquiry into the drainage of the Thames Valley as far as Windsor, under the direction of Lieut.-Colonel Ponsonby Cox, of the Royal Engineers. This course has been adopted at the instance of the Improvement Commissioners for the district of Surbiton. It is intended that the inquiry shall include Acton, Chiswick, Croydon, Ealing, East Moulsey, Epsom, Eton, Ham, Hampton, Kingston, Richmond, Staines, Surpiton, Teddington, Twickenham, Wimbleton, and Windsor. We trust that the inquiry will be impartially conducted, and that it will result in proposing some general scheme in place of the patchwork attempts that have hitherto been made throughout the district.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—With a view to aid in a proper representation of American Engineering progress and practice at the Centennial Exposition, this Society, at its Annual Meeting, appointed a committee to consider the subject, and to take such action as might seem desirable.

It is proposed to urge Engineers who are or have been in charge of important, novel or interesting works; railroad, canal and other public corporations, and especially builders or manufacturers willing to make their works known, to present such specimens, models, plans, photographs and descriptions as shall give to visitors at the Exposition an adequate and correct idea of engineering progress and practice in this country, and to exhibit the same either in groups or under the general classification as may be preferred.

It is also proposed to have a Secretary in attendance during the Exposition, to give such detailed information as by an inspection of the models, plans, &c., exhibited, visitors may be led to ask for.

It is expected that arrangements will be made to have memoirs prepared, setting forth the progress and present state of the several branches of engineering in this country.

With this view the following sub-committees have been formed:

I. On Railroads and Rolling Stock.
II. On Bridges and Bridge Construction.
III. On Water Works.
IV. On River and Harbor Improvements.
V. On Canals and Inland Navigation.
VI. On Hydraulic Motors and Machines.
VII. On Foundations and Masonry.
VIII. On Parks and Landscape Gardening.
IX. On Sewerage and Sanitary Engineering.
X. On Light-Houses and Signals.
XI. On Steam Engineering.
XII. On Metallurgical Engineering.
XIII. On Surveying and Geodesy.
XIV. On Gas Engineering.
XV. On Mechanical Engineering.
XVI. On Correspondence and Circulars.
XVII. On Rooms and Representation.
XVIII. On Arrangements and Space.
XIX. On Finance.

The Committee solicits assistance of members in the matter, either in contributing specimens, models, plans, photographs and descriptions to be presented, or by inducing others to do so. As the time is short, it is desirable that preparation should begin at once.

CIVIL AND MECHANICAL ENGINEERS' SOCIETY. Session 1875–76 of this Society will commence on December 9th, when the President, Mr. W. F. Butler, A.I.C.E., will deliver an opening address. The following is the syllabus of papers for the Session:—

Dec. 23d, 1875.—"London Bridge and its Traffic." By Mr. A. T. Walmaisley, C. E.

Jan. 13th, 1876.—"Trade Unions." By Mr. Charles H. Rew.

Jan. 27th.—"The Testing and Strength of Materials." By Mr. R. M. Bancroft.

Feb. 10th,—"Permanent Way of English and Foreign Railways." By Mr. W. C. Street.

Feb. 24th.—"Aquaria and their Construction." By Mr. C. H. Driver, architect.

March 16th.—"The Hoarworthy Bridge over the River Wye." By Mr. C. W. Whitaker, C. E.

March 30th.—"Concrete Flooring." By Mr. Alexander Payne, architect.

April 13th.—"Hydraulic Machinery." By Mr. Thomas M. Gray.

April 27th.—"The Spectroscope." By Mr. B. Haughton.

May 11th.—"Railway Rolling Stock." By Messrs. P. Burrell, C. E., and H. Valpy, C. E.

May 25th.—"Steam Tram Cars." By Mr. E. Perrett, C. E.

The annual meeting will be held on June 15th. Visits to various works in progress will be made during the session.

ENGINEERING SOCIETY, KING'S COLLEGE, LONDON.—A meeting was held on Friday, Oct. 15th, Mr. E. W. Anderson, vice-president, in the chair, and the minutes of the previous meeting having been read and confirmed, Mr. Crompton read a paper on "Railway Time Tables." The author began his paper by treating of railway unpunctuality as connected with and giving rise to accidents. He also looked for the cause of this unpunctuality as originating in the "time tables." He next discussed the reasons for and against the making of stations at the top of inclines; and then proceeded to consider and compare the fastest trains on each separate line running from London, making a few remarks on each. A discussion followed in which Messrs. Pollock, Kirkman, Little, Strange, and Mackworth took part. The chief object of the gentlemen who spoke seemed to be to show the error of certain statements made by the author, and the opinion given by him as to the desirability under certain circumstances of having six lines of rail where the traffic is large, formed the chief object of attack. Mr. Crompton replied, and the meeting adjourned, after a vote of thanks had been passed to Mr. Crompton, at 4.50 p. m.

GENEVAN SOCIETY OF ARTS.—On the occasion of the centenary of the Genevan Society of Arts, founded in 1776, that body proposes to offer a number of prizes in its various departments. A service which the Academy will render to horology will be the international competition in the regulation of pocket chronometers. The trials of these chronometers will take place at the Geneva Observatory, under the superintendence of M. Plantamour, the director. All chronometers intended for the competition must be forwarded to him before mid-day of February 14, 1876. All competitors not resident in Geneva should correspond with the Observatory through a resident agent, who will manage all the details. M. J. B. Grandjean, president of the Section of Horology of the class, offers his services gratuitously to makers who have no agent in Geneva. Each chronometer should be accompanied by a paper containing data to identify the chronometer, details of its construction, &c. The trial will last fifty-two days, from February 15, 1876, divided into nine periods. In a hot chamber and in an ice-house (*glaciere*), the chronometers will be tested by being placed in all possible positions. All chronometers not complying with the following conditions will be excluded from competition: 1. The mean variation from day to day ought not to exceed six-tenths of a second so long as the chronometer preserves the same position in the Hall of the Observatory. 2. The values which express the mean rates during each of the periods except that of the hot chamber and the ice-house, ought to agree with their mean in the limits of two seconds more or less. 3. The error of compensation determined by the comparison of the rates in the hot chamber and in the ice-house ought not to exceed two-tenths of a second of degree Centigrade. 4. The difference of rates between periods six and nine (both in the Observatory-hall, horizontal position, dial above), *i. e.*, before and after the proofs relative to temperature, ought not to be above one second in twenty-four hours. The value of the results obtained in the trials which concern the two former conditions will have an importance double that which will be given to the two latter. No competitor can receive two prizes. A sum of 3,000 francs at least will be devoted for the purpose of awarding gold medals, or an equivalent value, to competitors who have been judged worthy. A number of medals in silver and bronze will also be awarded. Those who wish for further details concerning this and other competitions should apply to the secretary of the academy.

IRON AND STEEL NOTES.

THE ORES OF IRON CONSIDERED IN THEIR GEOLOGICAL RELATIONS.—After some very interesting introductory remarks, Mr. Smyth said, omitting the discussion of certain silicates, rarely employed for smelting, and of iron pyrites, the ores to which he woudd direct the attention of his audience were simply the oxydes as met with by themselves, or combined with water or carbonic acid, and which formed the great bulk of the material employed in iron making. First in order of the ores thus limited was magnetite. This mineral, with 72.41 per cent. when pure, was the fine rich ore which had been worked with great success for centuries in several of the Scandinavian mines. In Italy fine examples of magnetite were also found, as well as in several widely-separated places in North America. Magnetite only occurred in a few localities in Great Britain, amongst which the vicinity of Penryn, in Cornwall, and Hey Tor, near Bovey, in Devon, were mentioned. In two localities in North Wales a minutely crystalline form of this mineral occurred, but it had never been opened out with perseverance, and was said to be in some places pyritons. The next species noticed by the lecturer was hematite. This ore so little recognized thirty years

ago, was now too well known to require to be enlarged on. Mr. Smyth, however, referred to its strange discovery in Furness, near Whitehaven, its having been worked for years in the Mendip Hills, and its occurrence in abundance in Spain and North America, the deposits in both these latter cases being of a bedded character. He next described the curious ores named bauxite and wochenite, in which alumina takes the place of the sesquioxyde of iron, turgite, gothide, limonite, chalybite, the last named often mixed with other ores on a larger scale. The most important deposit of this last-named ore was contained in the range of veins occupying a length of some thirty miles in Somerset and North Devon from the Raleigh's Cross westward to near Ilfracombe. There was also the fine lode of Perran, sometimes 100 feet across, if taken horizontally from wall to wall, where workings commenced in brown ore had opened downwards, at depths of from 30 to 120 feet, into large masses of chalybite. The varieties of ironstone next referred to, in which the carbonate was mingled with a very variable amount of clay, of lime carbonate, or of carbonaceous matter, were, the lecturer said, thoroughly well known from their wide diffusion over the country and their commercial importance. They were, in fact, objects of more interest to the smelter than to the mineralogist. Certain of these, as the celebrated Cleveland ore, dated their employment from a very few years ago; others, like the dark pisolitic masses of the palæozoic schists of Anglesey and North Wales had hitherto met but little attention. Proceeding next to show the relationship between the oxydes, the lecturer exhibited a specimen of ore having the appearance of chalybite or spathic ore, being covered with the large rhombohedral crystals characteristic of that species, but which the presence of the brown streak, and of water, and the percentage of iron proved to have been turned into brown ore. A fragment from the lodes of the Deerpark in Exmoor, next shown, had also lost its carbonic acid, had acquired oxygen and water, and actually become a different substance. The first stage of the change might be observed in heaps exposed on the shaft tips even for a few months; a brown tint, heightening with time, took the place of the yellowish gray, and showed that a chemical action attacked the exterior, and proceeded towards the interior. It had been argued that the change commenced with the formation of the more hydrated species, and passed through successive stages to those with the least amount of water; but on that point evidence was as yet defective. The brown ores were undoubtedly (for the process might be watched in the workings) formed by another series of changes from pyrites through the sulphate of iron. The crystals of brown ore, in the form of pyrites, were among the best known pseudomorphs, and there were localities which invited the inference that this action had taken place on an important scale. To proceed a step further, it had long since been argued that red ore was a pseudomorph of brown ore, and the most notable of the proofs adduced was that from a specimen from Rostermel, which ultimately, however, turned out to have been manipulated by a roguish dealer. At the same time it had been shown by Morgans that a good deal of red ore had been found in the Raleigh's Cross vein, which might probably have passed through the intermediate hydrated stage. Mr. Smyth said he would not, in the present brief sketch, venture upon the vexed question of the original deposition of the great northern masses of hæmatite, although strong arguments for their having been chalybite might be adduced from the occurrence of limestone fossils turned into red ore. In conclusion, he brought under notice another change of condition among the oxydes of iron. It was a significant fact that magnetite was characteristic of the older formations—of those bodies of rock which had during the longest period of time been exposed to the influences which bring about metamorphosis and change of substance. In the Perran lode small portions of magnetite had been formed among the brown ores near the surface. In some of the Cornish copper lodes specimens of magnetic ore had occurred which looked very much as if they had been carbonates, and amongst the beautiful red ores of Siegen small grains of magnetite appeared to testify to a partial change, while there appeared to be sufficient grounds for believing that, in many cases at least, this last change in the degree of oxydation might be produced by the ordinary action of natural causes.

RAILWAY NOTES.

M. Herzog, engineer-in-chief of the Hungarian railways, after a series of experiments on the magnetization of rails, gives the following as his conclusions:—(1) The rails, which are taken up and replaced after several years of service, do not by any means deserve to be called powerful magnets, since a steel rail about 40 square centimetres, 6.16 square inches, in cross section, manifests immediately upon its removal a magnetic force scarcely equal to that of a saturated steel plate half a square centimetre in section. It is to be observed, however, that steel rails possess a much higher magnetic power than rails of ordinary iron. (2) Rails in place are also magnetic, and this whether the fish-plates are removed or not, provided there is between them the space usually allowed for expansion in all well-constructed lines. (3) Rails removed from the roadbed and piled up show traces of magnetism even after many months. This persistence of the effect is more pronounced in Bessemer rails than in those of ordinary iron. (4) A rail thrown out of use in consequence of fracture shows on the two surfaces of separation opposite polarities. This is precisely the same fact which is observed when a magnetized bar is fractured; there are as many magnets as there are pieces. (5) Entirely new rails, which have never been in actual service, acquire feeble magnetic properties when they are arranged in piles and placed parallel to the magnetic meridian. This remark applies more

particularly to steel rails, which, under the influence of a few blows with the hammer, are converted into permanent magnets. This last observation leads M. Herzog to the conclusion that all these phenomena are attributable to terrestrial magnetism, and are only a confirmation of the following theoretical principles: (*a*) A bar of iron placed in the direction of the dipping needle, becomes a magnet under the influence of terrestrial magnetism. The same is true for any bar of iron placed in the magnetic meridian; its magnetic intensity diminishes in proportion as the angle between the two increases. This fact is very noticeable with rails laid on a curve; the more they vary from a north and south direction, the less intense is the magnetism at their ends. (*b*) A bar of iron exposed for a long time to the influence of terrestrial magnetism becomes a permanent magnet. (*c*) For steel rails, the effect is more prompt, and more intense than for iron ones. Under the action of the hammer, they become permenent magnets. This latter effect is produced daily upon rails in use, since they are submitted at the same time to the combined influence of terrestrial magnetism, and the jars produced by the passage of trains.—*Engineer.*

The speed of trains in Germany is illustrated by a report of the railroad bureau of the empire for the month of December last. It states that the greatest speed per hour, including stops at intermediate stations, was, for express and fast trains, 34 miles on the Beflin, Potsdam and Madgeburg road; for ordinary passenger trains, 25 miles per hour on the Maerchen and Posen road. The slowest speed was for express and fast trains 21 miles per hour on the East Prussia Southern Road; for ordinary passenger trains, 16 miles per hour on the Ermsthal and the Cromberg roads of Wurtemburg. The average speeds per hour were, for express and fast trains, 28 miles; for ordinary passenger trains, 21 miles. This is for the whole empire, except Bavaria.

The Winchell Car Ventilator.—This apparatus, which has been recently tested on a car of the Cincinnati, Hamilton and Indianapolis Road, is thus described:—"The apparatus consists of an air-chamber attached to the roof, and extending the entire length of the car. Each end is supplied with a hood protected by very fine wire gauze screens, through which the air and nothing else is admitted to the chamber. Each drum is furnished with a cut-off, operated by a lever within the car, by means of which the supply of air may be regulated to a nicety. A number of registers in the bottom of the chamber admit the air to the car. When the train is in motion, the cut-off in the forward end of the car is opened, and the air enters, passes down through the registers into the car, and, having served its purpose, makes its exit through the rear hood, or, if the windows are open, through them In connection with this air chamber, and for summer use only, are deflectors on the outside of each window, which, acting as an exhaust, not only draw out the impure air from the car, but prevent the admission of smoke, dust, cinders and rain through the open window. These deflectors, being made of glass, do not in the least impede the view from the windows. They are operated all at once, by means of an iron rod running along the side of the car."

The Collision at Kildwick.—In consequence of a statement made by one of the principal officers of the Midland Railway Company, with reference to the collision at Kildwick, to the effect that the engine-driver of the mail train would have been able, with the means at his disposal, if traveling at the rate of 50 miles per hour, to stop his train in 400 yar is, certain brake experiments were made in the presence of Captain Tyler on the Derby, Castle Donnington and Trent line, recently. There were four trials. In the first of these experiments, tender brake and one guard's van brake at rear of train were applied, sand used, and engine reversed and steam against it, with the Le Chatelier tap open. The gradient was level; the train was running at the rate of 49.9 miles per hour when the brake was applied. The result was that 54 seconds were occupied in stopping the train in a distance of 807 yards. In the second experiment the same means were used except reversing the engine; gradient 1 in 330 up and level; speed 49.9 miles; time occupied, 60 seconds; distance run, 843 yards. In the third experiment when the engine was reversed, the regulator was allowed to remain open all the time; gradient 1 in 220 down; speed, 52.5 miles; time occupied, 55 seconds; distance run, 867 yards. In the final experiment all available means were used. When reversing the engine the steam was first shut off, then the lever was pulled into back gear, and then steam was turned on again as in first experiment; gradient, level; speed, 52.5 miles; time, 50 seconds; distance run, 787 yards. Captain Tyler, in his report to the Board of Trade, states that the engine-driver of the mail train, who at present awaits trial on the charge of manslaughter, could not have acted so promptly as those who on the experimental train listened for the word of command. He adds that instead of 400 yards 800 yards should have been stated as the distance in which, with the assistance of the guard, he could have stopped his train.—*Engineer.*

ENGINEERING STRUCTURES.

New Ship Canal for St. Petersburg.—St. Peter burg without being itself fortified, occupies, from a military point of view, a very favorable and safe position, it being bounded on the land side by large impassable marshes, while on the side of the sea it is protected by water of a very small and changeable depth, no war ships of size and draught being able to enter St. Petersburg from the Gulf of Finland. It will be remembered that in the Crimean war the fortifications of Cronstadt, not on account of their excellent condition, but because of their being surrounded by very shallow and changeable water, were sufficient to prevent the combined English and French fleet from entering the harbor of St. Petersburg.

These circumstances, however favorable from a military point of view, are the cause of great and constant inconvenience, and considerable expense. No large mercantile vessel can convey its load direct to St. Petersburg, and this circumstance is so much more to be regretted as the River Neva itself offers no obstacle whatever to navigation, it having on its course through St. Petersburg a depth varying from 14 ft. to 53 ft.

As in the case of the mouths of most large rivers, the Neva has formed in the course of centuries enormous sand-banks, which still further enlarge through constant heavy west winds, offer great difficulties to navigation. These sandbanks reduce the depth of water in the different arms of the Neva to from 7 ft. to 8 ft., thus preventing ships from entering the river itself, which, as we have said, is sufficiently deep.

Some time ago a company was formed under the leadership of Mr. Kutiloff, to avoid these obstacles, and with the intention of constructing a harbor in the immediate neighborhood of St. Petersburg, it being proposed to connect this harbor with the deep water of the Gulf of Finland, near Cronstadt, by a canal.

According to the project of Mr. Kutiloff, this canal is to be built with a width varying from 260 ft. to 660 ft., and with a constant depth of 20 ft., while it is intended that the material cut out from this canal shall be utilized in filling up the marshy islands and in forming the harbor and dock arrangements at St. Petersberg.

The length of the canal will be about 16.4 English miles, and the cost has been calculated at £1,400,000. The material to be removed will amount to about half a million cubic yards. The dredging is expected to give much trouble on account of numerous large blocks being met with in this bay, the removal of which will incur much expense and trouble. The whole amount of earthwork to be removed for the harbor and canal is calculated to be about 60 million cubic yards, and the time for completion as five years. Considering that in the Russian climate only about 105 days per year can be counted as working days for this class of work, a daily amount of 18,000 cubic yards of material will have to be removed, if the work is to be completed in the stated time. The cost of excavating the harbor has been estimated at £1,200,000, the cost for a connecting canal between this harbor and the Neva, at £300,000, the railway to connect the harbor with the principal Russian lines at £300,000, and for other purposes, buildings, stores, &c., £800,000, making a total of £4,000,000. If, however, as is very probable, it is necessary to build a railway bridge over the Neva, another £800,000 will be added to this cost.

The importance of these improvements to the mercantile position of Russia will be best understood by referring to the losses caused by unloading all ships at Cronstadt. According to a recent statistical report the cost of unloading large vessels, reloading the goods into smaller ones and transporting the latter to St. Petersburg, amounts to about £1,137,500 per annum, not counting a large amount of damage and delay caused by reloading the goods.

The importance of this undertaking for commercial transactions has so fully been appreciated by the Government, that the latter has decided to undertake the construction and cost of the canal, leaving the harbor arrangements, and all connected with these, to public enterprise only.

Part of these works were opened for competition last autumn, and Mr. Elim H. D'Avigdor sent a tender for the firm of Antonio Gabrielli and Co., contractors, to the authorities of St. Petersburg for the complete work of the canal. After these works, however, had been given to the Russian contractor, Mr. Pontiloff, Mr. D'Avigdor was requested to examine and report upon the plans and estimates, and according to this report, several alterations and improvements will have to be made in the proposed details. The cross sections of the canal, as well as the pierheads on the entrance dams, will require considerable modification, the slopes of the former being in all probability too steep; these alterations will, of course, also increase the cost of the undertaking. For the information on this subject we are indebted to Mr. D'Avigdor.

It is to be hoped that the Russian Government will give all possible support to this beneficial undertaking, and have its own share of this work carried out with the utmost speed and energy, because, with the constantly increasing mercantile importance, and the unfavorable climatic conditions, this is a question of very great importance. By means of suitable steamers this small "water-street" may be kept open throughout the winter, and an easy and constant communication thus secured between St. Petersburg and Cronstadt.—*Stummer's Ingenieur.*

ORDNANCE AND NAVAL.

HYDRAULIC MACHINERY FOR ARTILLERY.—A series of interesting experiments have just taken place on board the "Thunderer," turret ship, off the Isle of Wight. Some patent hydraulic machinery, invented by Mr. Rendel, and from Sir William Armstrong's factory, was on trial. By the machinery, the gun-turret was revolved, and the two 38-ton guns within it were elevated, depressed, loaded and moved in and out. The total weight of the turret with the two guns and carriage is something like 330 tons. Fifty rounds were fired; and the trial is reported to have been highly satisfactory.

BREMNER'S STEAM STEERING SCREW.—Unfortunately more than one fearful catastrophe has of late directed our attention towards the want of an efficient means of turning and manœuvring vessels, for this branch of naval architecture has, we are sorry to say, by no means kept pace with the rapid strides which have been made in other studies of the profession. The introduction of long ships into the royal navy first brought home to naval architects the feebleness of the power of the ordinary rudder over such ships as the Minotaur and Bellerophon, and the balanced rudder

was introduced, by which a greater area of rudder surface could be employed at the same expense of manual labor necessary to put over the ordinary rudder. The advisability, however, of using some further power besides the rudder in order to insure quick manœuvring was pointed out by Mr. Barnaby in 1863, when he proposed the adoption of a transverse steering screw, some 10 ft. in diameter, placed in the bow of a ship, for he thought that if such a screw were connected with a small engine on the deck or in the forehold, there would be no difficulty in driving it at a speed of eighteen knots per hour, and that thus both increased speed in turning and the means of turning on a pivot from rest would be obtained. In the following year the Astronomer-Royal also brought forward the subject of a transverse screw in a paper he read before the Institution of Naval Architects, and particularly pointed out the benefit which would accrue from its use in ships of war when engaged in line or lying head and stern, as our ships were at Kertch, and when it is desirable for the precision of fire that a vessel should be so steady that the guns may be trained by marks on deck, since these are the circumstances under which it would be of the greatest importance that there should be a power, independent of the motion of the ship, of swinging her round. The method which Professor Airy proposed was a transverse screw placed in a tunnel, so that when it revolved it would pull in the water from one side and project it from the other, thus making, in fact, a jet propeller, and this plan was afterwards tried in the Hooper telegraph ship, by Sir W. Thomson and Professor Fleeming Jenkin, but as they placed their tunnel a distance of 50 feet from the stern of the vessel in a well, it failed to gain sufficient leverage—in fact, only churning water. This failure brought transverse screws undeservedly into disrepute, for on investigation it will be seen that they had hitherto failed for want of being properly applied in a practical manner. There can be no doubt that, if rightly applied, the greatest benefit would accrue from their employment, and this desideratum has apparently been arrived at by Captain Bremner. Captain Bremner has had the failures of others before him as a guide "how not to do it," and appears to have taken very great pains to arrive at the proper method of application. Still there is no doubt that these previous failures will have prejudiced the minds of many people against transverse screws altogether; but we venture to think that when they examine Capt. Bremner's plan, they will at once see its peculiar advantages. It will be seen that Capt. Bremner places his transverse screw in the extreme after dead-wood of the vessel, as low down as possible under the line of the main screw shaft. He works it by steam power by means of shafting geared on to the boss of the screw, this shafting being placed either vertically or parallel to the main shaft, according as may be most convenient. This position is now allowed by practical men, and certainly seems, to be the right one for placing the screw; for, with the same leverage as is obtained at the bow of a vessel, there is the additional advantage of the screw being fed by the water thrown back from the face of the rudder, which would naturally be put hard over whenever it would be necessary to use the transverse screw either under sail or steam, and, of course, when the vessel was stationary there would not be the same fear of the water slipping past the screw as there might be when she was under weigh. A vessel provided with a screw of this description, working well, would gain incalculable advantage in making her way through a crowded roadstead, or into such docks as those at Southampton, where the entrance is narrow and intricate, and where now it is necessary to spend a long time in warping in. The wonderful benefit, too, which such additional power would be to vessels when under imminent risk of collision need hardly be enlarged upon. The case also of the Bessemer running into the pier at Calais is one in which we believe such a contrivance as the steam steering screw would have made all the difference, and enabled her to make that most difficult harbor at slow speed in safety. Calais harbor is about 110 yards wide, and though inside it the water is comparatively smooth even on a very rough day, the tide runs like a sluice just outside it, and at right angles to the entrance, and, consequently, when a long vessel has got half in and half out of the harbor, the after end is caught by the tideway and slewed round, thus turning the bow right into the pier, in the manner which will be well remembered by all those who were on board the Bessemer on the occasion of her memorable trial trip. Had, however, that unfortunate vessel been fitted with an efficient transverse screw, we feel no hesitation in affirming that the result would have been very different. We understand that the Bessemer is still for sale, and it is evident that unless something is done to improve her, she is likely to remain a drug in the market. We have already suggested that her swinging cabin should be taken out of her, as we look on it, in its present form, as a device which can never be made successful; but her steering power must also be improved, and this, as we have pointed out, we think could be effected by means of Bremner's steam steering screw, and if these alterations and improvements are made in her, we may yet hope to see her doing good work between England and the Continent.

The cases of collision which have recently brought the vessels of the royal navy so prominently into public notice, have also shown how desirable it is that they should possess some auxiliary power to assist them in turning, not only to avoid collision, but also to escape from the ram of an enemy. There is no doubt that if ramming is to be the greatest object in future warfare, the handiest vessel will necessarily have the chief advantage. But as ramming is only a matter of close quarters, the effectiveness of the guns is also a matter of the highest importance. Now, the turret system was introduced in order to enable a ship to bring her guns to bear on her opponent with a maximum of effect and minimum of danger to herself. Since, however, turrets have in our cruising iron clads given way to broadside batteries, the necessity of having additional power

to turn the ship herself quickly is still more imperative. Much stress has been laid on the power of twin screws to assist the rudder in turning and manœuvring vessels, but, as we remarked recently, when dwelling on the loss of the Vanguard, very grave objection exists in the use of twin engines in ships of war, on account of the necessity when they are employed of doing away with the wing passage bulkheads, which curtail so much of the space they require.

As we have already stated, the application of a transverse steam steering screw was proposed by Mr. Barnaby before the introduction of the turret system, and we understand now that the authorities at Whitehall have again turned their attention to the matter, and that Captain Bremner's plan has been received with much favor. We may, therefore, hope to see a trial made with one of these screws before long, and if the results prove as good as is anticipated by the inventor—who claims to be able by this means to turn one of our longest ironclads in four minutes—there is no doubt but that we shall have placed at our command a steering apparatus of the greatest service both for peace and war.

BOOK NOTICES.

NOTICE SUR LA MARINE A VAPEUR DE GUERRE ET DE COMMERCE, par L. E. BERTIN. Paris: Dunod. For sale by D. Van Nostrand. Price, $2.00.

This work is divided into two parts, the first treating of General Principles of Naval Architecture; and the second of The History of Steamship Navigation.

The author deals only in historical notes and technical descriptions. It is a convenient compend of present knowledge of steamships.

ELEMENTS OF THE DIFFERENTIAL AND INTEGRAL CALCULUS. By Prof. C. P. BUCKINGHAM. Chicago: S. C. Griggs & Co. For sale by D. Van Nostrand. Price, $2.00.

This is a text-book for beginners in calculus, and the author has given an unusual amount of space to the elucidation of the first principles.

The details of the method of presentation seem to be the author's own; the general plan being founded on that of Sir Isaac Newton, without use of infinitesimals or limits, and by reason of the fullness of the elucidation of first principles, appears suitable for students working without an instructor.

A MANUAL OF ELECTRO-METALLURGY. (Fifth Edition.) By JAMES NAPIER, F. R. S. E. For sale by D. Van Nostrand. Price $3.00.

This excellent manual is widely known. The first edition appeared in 1851. The new editions have steadily kept pace with modern discovery, and the work has thus won a prominent place as a standard for the practical worker. The relative merits of all the ordinary forms of battery are clearly and concisely set forth. The practical uses of galvanism are placed first, and the theoretical considerations occupy but small space.

Among the additions to the former books we notice the description of the magneto-electric engines.

HOW TO BUILD SHIPS: AN ESSAY UPON THE WEAKNESS OF LARGE IRON STEAMSHIPS; WITH RECOMMENDATIONS FOR MAKING THEM STRONG. By a SEAMAN. New York: D. Van Nostrand. Price, 75 cents.

The writer of this Essay is evidently a seaman of wide experience, and possessing in a high degree the instincts of an engineer. The essay is presented in three parts: the first treating of deficiencies in present modes of ship construction; the second is devoted to recommendations of methods for the cure of such faults, and the third is supplementary, so far as matter is concerned, to the second part.

The work is eminently practical in its suggestions, and is still free from unfamiliar nautical or ship nomenclature; fulfilling the promise in the introduction that "technical phrases, except those that are generally well understood, are' not introduced, nor mathematical forms or inquiries. The object in view is to present a solution of the difficulties that seem to surround a very important industry, in a manner that can be easily comprehended by the man of business, as well as by the man of practice and the student of science."

REPORT ON THE COMPRESSIVE STRENGTH, SPECIFIC GRAVITY, AND RATIO OF ABSORPTION OF THE BUILDING STONES IN THE UNITED STATES. By Q. A. GILLMORE, Lieut.-Col. Corps of Engineers, Brevt. Maj.-Gen., U.S.A. New York: D. Van Nostrand. Price, $1.00.

The eminently practical character which renders Gen. Gillmore's published works so valuable to the working engineer is in no case more manifest than in the present work.

We have here in tabulated form the results of careful experiments upon all those properties of building stone which are of use in engineering structures.

The methods followed in each line of experimenting are minutely described, and where an original plan is followed the reasons therefor are fully given.

We make an abstract of the author's discussion on modes of experimenting on compressive strength:

"No one can doubt the usefulness of experiments to obtain the crushing and tensile resistance of cast or wrought iron, or steel. But having these—the compressive and tensile strengths of cast iron, for instance—and combining them together to calculate the strength of a rectangular beam, we should find on 'testing the beam that we had wasted a large amount of material, and that it was much stronger than the results obtained by calculation indicated. Besides, therefore, the abstract knowledge of crushing-strength which we possess, we must also, by some series of experiments, combine these and other relations so as to learn whether, as in the case of beams and columns, there may not be new forces born of the combination, an acquaintance with which would materially add to our constructive power.

"Connected with our subject, and therefore

of special interest, is the discussion made by Mr. Hodgkinson in regard to the breaking of short prisms for the purpose of finding the exact crushing-resistance of cast iron. Discovering in his earlier examinations that when these were shorter than their sectional diameter they resisted to a far greater extent than the metal could do as used practically, he thenceforth ignored such tests, beyond the simple fact of their existence, and confined his trials to prisms having a height of one and one-half the diameter or more, *because there the material gave way by the same laws, and in the same manner, as it does when used to guard human life, or secure valuable property.* In these trials he first discovered the angular breakage of material, and the law of constant direction, under the same conditions.

"In making experiments on stone, it would, from the different nature and uses of the material, be evidently improper to follow blindly the modes used for cast iron. Here are no flanged girders or hollow columns to form culminating points of inquiry. Yet in principle we have the same necessity for reasoning directly towards the end to be ultimately attained, to watch carefully the character of the material, its mode or modes of yielding, the uses to which it is daily put, the peculiar stresses and strains which come upon it, and all this, not as an individual stone which our curiosity has induced us to investigate, but as the integral part of some vast natural structure taken down little by little, and transformed into smaller artificial edifices.

"In regarding the idea of a crushing-force, the mind is too easily led to conceptions of vertical lines of strain, reaching directly from the weight at the top to the foundation at the bottom. It need hardly be said to engineers that such strains have existence only in the pages of mathematical applications, and could only be possible under the hypothesis of a film of material only $\frac{1}{100000000}$ of an inch, or one molecule thick. So soon as another film is superadded, oblique arangements of molecule and strain would intervene under pressure, and tangential stresses would be developed. If this were not true, there would be no such phenomena as angular breakage, spreading under weight, nor any need for bond on masonry, but blocks of stone, or brick, or any materials, piled vertically one upon another, would, under a destructive load, be gradually compressed into a smaller volume, *within the limits of their original horisontal dimensions.*

"In good masonry, in which the strength of the structure depends upon material and bond, stones should never be used of greater height than the breadth of the bed. Our experiments, then, unless we should purposely test for columnal strength, would not be made on objects over a cube in height. But earlier experiments showed that the cube gave quite sufficient opportunity for the natural angular breakage of stone, and subsequent trials with homogeneous kinds prove that, while slabs less than a cube in height, pressed by unyielding surfaces, gave much greater resistance than cubes, those higher than the cube to the limit of nearly three times the width were but little if any decreased in resistance by increased altitude. The cube, therefore, was the form depended upon for specimens; a determination carried out with greater satisfaction from the knowledge that other experimenters with stone had, for perhaps other reasons, arrived at the same conclusion."

We shall make fuller extracts in a future article.

IVESON'S HORSE-POWER DIAGRAM. London. For sale by D. Van Nostrand. Price, $4.25.

Under the title of a "Horse-Power Diagram," Mr. T. G. Iveson has produced a very useful office companion. It consists of a diagram admirably engraved by Mr. Thomas Kell, mounted in a folding cover and accompanied by some explanatory letter-press, pointing out its objects and the manner in which it is to be used. The diagram, which consists of straight lines only, enables a number of calculations to be made by simple inspection and measurement by scale. Thus, given a certain size of cylinder, speed of piston and mean effective pressure (or initial pressure and ratio of expansion), the horse-power can be obtained almost at once. Similarly there can also be calculated the steam consumption in cubic feet per hour, the water consumption corresponding to the quantity of steam at different pressures, and a variety of other problems which have to be constantly worked out by those engaged in designing steam machinery. The diagram has been drawn with very great care, and so far as we have tested it, it is very accurate. The letter-press which accompanies the diagram might, we think, be improved, and the use of the diagram be more clearly explained. There is, however, nothing very complex about the use of the diagram, and a very short examination of it will be sufficient to enable any draughtsman to understand its principle, and render himself familiar with its use. As a contrivance calculated to save much time, Mr. Iveson's diagram is well worthy of a place in every drawing office where steam engines are designed.

THE NEW GUIDE TO THE LOCAL MARINE BOARD EXAMINATIONS FOR ENGINEERS FOR CERTIFICATES OF COMPETENCY; AND FOR MASTERS AND MATES FOR CERTIFICATES IN STEAM. By JOHN TURNBULL, Jr. Glasgow: James P. Forrester.

Last year the Board of Trade issued to the different Examining Boards a new series of 188 questions for use in the examination of candidates for certificates of competency, each candidate having proposed to him eight of these questions selected at will by the examiner. To these 188 questions, Mr. Turnbull has drawn up concise answers, and these answers form the chief contents of the book before us. Each answer forms a paragraph complete in itself, and the whole have been prepared with great care. In his preface, Mr. Turnbull very properly recommends that students should study the larger works treating in detail of the subjects to which his answers relate, and it is indeed evident that these "answers" are in no way intended to replace treatises on steam engineering. They are, however, calculated to

form a valuable aid to those preparing for a local marine board examination. Mr. Turnbull's volume also includes in its contents the Act of Parliament relating to engineers' certificates, and the official notices of the Board of Trade regarding such certificates. The book is altogether a very useful one for the classes for which it has been written.

THE RELATIVE MERITS OF SIMPLE AND COMPOUND ENGINES AS APPLIED TO SHIPS OF WAR. Prize Essay. By NEIL MCDOUGALL, A. I. C. E., &c. London: Griffin & Co., 1875. For sale by D. Van Nostrand. Price, $2.25.

The essay, including an appendix dealing with the well-known United States inquiry carried out by Mr. Loring and Mr. Emery, with the ships, Bache, Rush and Dexter, is published in the form of a thin octavo of 87 pages; and it is due to the publishers to state that the type, diagrams, and tables leave nothing to be desired. The work is remarkably free from typographical errors, which it is almost impossible to keep out of a technical work. The essay affords internal evidence that Mr. McDougall brought with him to the task of its preparation two admirable qualifications. In the first place, he knew perfectly what he was going to write about; and, in the second, how to write about it. In other words, he is not only familiar with all that has been done in the navy with compound engines, but he possesses a really masterly style. His English is terse, grammatical and explicit, and the way in which he has arranged his matter is so good that we, at all events, confess to being unable to suggest an improvement. It is true that our author might have said more on certain points, but then he would have exceeded the limits at his disposal. Mr. McDougall has grouped his conclusions in the following order:

"First, the great aim in designing machinery for ships intended to fight under modern conditions being to obtain maximum security against disaster under fire, with minimum complexity of parts, the compound engine at its best is altogether inferior to the simple engine in this respect. Secondly, the economy of the modern compound engine is due to the use of high steam pressure. Thirdly, there is no insuperable difficulty in the way of working simple engines at the same pressure as that in use at present with the compound engine at sea. Equal economy might then fairly be expected with the simple engine, specially fitted, as with the compound under ordinary conditions. Fourthly, even if this was not the case, it would still be safest to use the high-pressure simple expansive engine under the present system of ship and boiler construction in use in this country. Fifthly, all available evidence goes to show that it is impossible that the compound engine can be to any serious extent superior to the rival engine at present pressures in point of economy."

MISCELLANEOUS.

PENCILS have lately appeared, the writing of which is capable of being copied, more or less perfectly, in the press. They are said to be made of a mixture of graphite, kaolin and blue violet aniline. The graphite is used in the form of a thick paste, the kaoline in a finely pulverized state, and the aniline in the form of a very concentrated aqueous solution. The whole when well mixed is moulded under the press with cylinders about four inches long and of the required diameter. Gumarabic may be substituted for the kaolin.

A NOVEL method of propelling canal boats has lately been introduced in Belgium, as follows:—The towpath is laid with a single rail, weighing some 16 lb. to the yard, and fixed on traverses a little more than three feet apart. The locomotive has four wheels, two of which are placed directly along the axis of the vehicle, one in advance of the other, and the others one at either side. The first pair are directing and the second driving wheels. The directing wheels are grooved and fit the rail; the others have rubber tires, which give purchase on the macadamised road, and which press thereon to the extent of 0.07 lb. to the square inch. By means of a simple mechanism, the weight of the machine may be thrown upon either the driving or directing wheels at will. In the former case the maximum and in the latter the minimum, of adherence is obtained, to suit the conditions of a loaded or an empty boat. There is but a single road, with rotary engines provided at suitable distances. Each locomotive tows one boat; and when a meeting takes place of two travelling in opposite directions, the engines change boats and retrace their paths. The locomotives weigh four tons each, and travel about three miles an hour, with full boats carrying a cargo of 150 tons each.

JAPANESE VARIEGATED FOIL—Professor Liegg, of Japan, writes to Europe to describe a process used by the Japanese in the production of a metal leaf used for decorative purposes. Thirty or forty thin plates of gold, silver, copper, and various alloys, are laid one over the other in a given order, and soldered together at the edges, so that the whole forms a stout plate of metal. Punches of various shapes, conical, pyramidal, with triangular, square or pentagonal sides, are now used to make a pattern of perforated figures, which exhibit on their inner sides concentric circles, triangles and other forms, corresponding to the punches used. The plate so prepared is hammered and rolled until it has become quite thin, the holes disappear, and the figures have spread out, preserving, however, their parallelism. A number of broken, straight and curved lines are thus produced, which, as in a Damascus blade, are free of each other, though consistent in themselves in the same metal, their effect being further enriched by the use of acids to modify the colors. It will easily be understood that thin plates prepared in this way, having an extremely flexible nature, admitting relief, with stamped or engraved designs, and capable of receiving the most various colors and forms, will have many uses in decorative art.

Instrument for Measuring Radiant Heat Emanating from Inclined Incandescent Discs.

by CAPTAIN JOHN ERICSSON.

[SEE PAGE 194.]

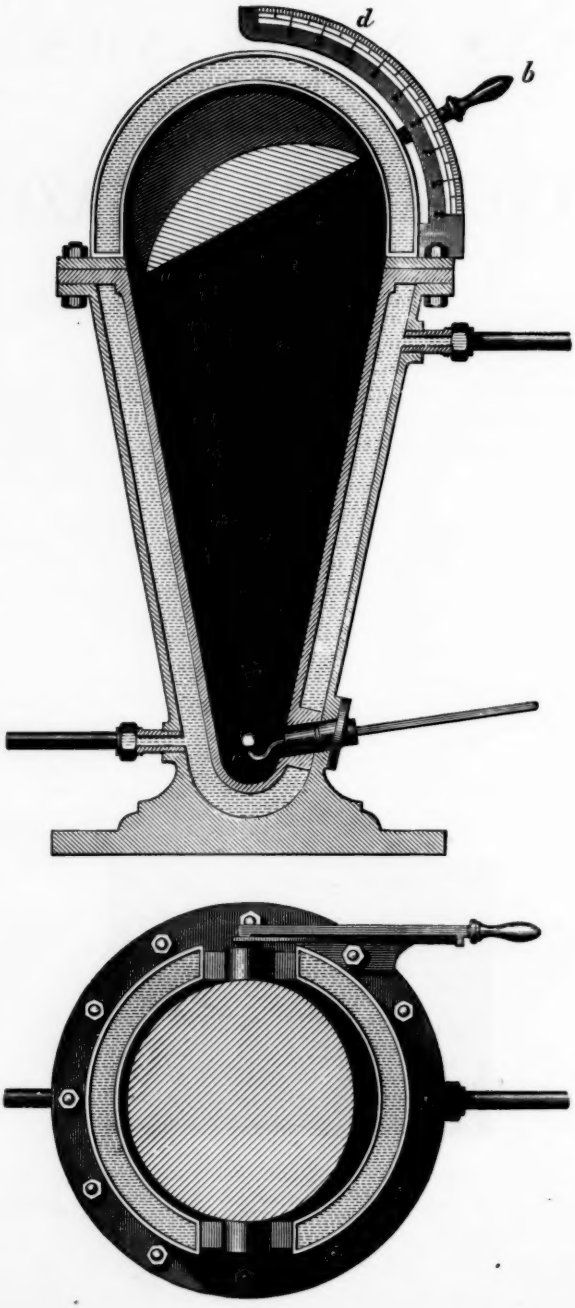



FIG. 2.